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SCIENTIFIC AGRICULTURE

VOLUME 32 APRIL, 1952 No. 4

WINTER INJURY OF TREE FRUITS IN BRITISH COLUMBIA IN 1949-50[1]

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[Received for publication August 16, 1951]

INTRODUCTION

The particular tree fruit region of British Columbia dealt with in this paper extends from Lytton, Lillooet and Kamloops in the north, to Osoyoos and Keremeos in the south. This region may be divided roughly into a northern and a southern area, the former centring on Vernon, the latter on Penticton. Between these two areas lies a central district adjacent to Kelowna, which is intermediate in climatic features. The approximate length of the entire region from north to south is 200 miles.

The lowest temperatures ever recorded in the above region were experienced in the winter of 1949-50. However, during the past 58 years there have been at least 4 winters in which temperatures in the colder fruit areas of this region have dropped to −30° F. or lower. In 4 more winters, temperatures fell to below −25° F. and in 21 additional winters, temperatures of −15° F. or lower were recorded.

In these cold winters the more favoured southern fruit area experienced less extreme temperatures than the northern districts. Neverthless, in all areas, winter injury has been one of the limiting factors in the production of the various kinds of tree fruits. In the more northern districts there has been frequent injury to apple and pear trees, and production of stone fruits has been very hazardous. In the southern districts apple and pear have seldom suffered seriously from low winter temperatures but stone fruits have been injured periodically.

Of the various severe winters experienced, the winter of 1949-50 was outstanding for its prolonged sub-zero weather, and severe injury to fruit trees resulted throughout the Okanagan and adjacent valleys. Approximately 337,000 trees, or about 20 per cent of all fruit trees in the southern interior of British Columbia, were reported killed after this winter.

During the winter of 1949-50 temperatures in the more northern districts dropped to between −40° F. and −26° F., and in the southern apricot- and peach-growing area temperatures of −24° F. to −16° F. were recorded. Sub-zero temperatures were frequent in all districts during January and early February 1950. This resulted in extremely low mean temperatures for January 1950, as compared with average January mean temperatures (Table 1).

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TABLE 1.—TEMPERATURES FOR JANUARY

Weather record station	Years records taken	Mean temperatures for January	
		Average	1950
		° F.	° F.
Vernon (Coldstream)	55	22	−3
Summerland	32	26	4
Oliver	26	26	7

Snowfall throughout the fruit areas was moderately heavy and in the northern districts the snow remained on the ground during the severe cold and provided adequate root and crown protection. In the districts south of Peachland, however, there was a brief thaw prior to the extremely cold weather, and this thaw was sufficient in many cases to melt the snow immediately around the trunks of the larger trees, leaving the ground at the crown bare. In some southern areas the snow covering was removed by strong north winds.

METHODS

As soon as it became evident that conditions sufficiently severe to cause extensive injury had occurred, plans were made for a comprehensive survey both in the Station orchards and in commercial plantings throughout the fruit areas. This work was begun in March and continued until late autumn.

On the Station every tree of bearing age was examined at least once to record injury, if any, to crown, trunk, framework and fruit buds. Investigations on the Station covered 263 apple, 135 apricot, 111 cherry, 289 peach, 50 pear and 80 plum trees, a total of 928 trees.

Several thousand trees in 206 commercial orchards were examined, many of them a number of times during the season.

In the examination of trees early in the spring, incisions were made in bark, cambium and wood, at least on the north and south sides of the trees. The amount of injury was evaluated from (1) the discoloration of tissue and (2) the recovery or building of new tissue.

During late spring, summer and autumn all injured trees were inspected, some of them as many as 6 times, and the degree of gradual dying or recovery, as evidenced by the appearance of foliage and new growth, was evaluated. Written records were supplemented by over 300 photographs in colour.

Of the injured trees on the Station, 261 were excavated and subjected to a thorough examination as to the extent and kind of injury to various parts of the tree. The bark was sliced off in wide areas and an evaluation was made of the amount of injury in the bark, cambium and wood of the roots, crown, trunk, main crotches, large branches, small branches and twigs.

The hardiness of fruit buds was evaluated by comparing total fruit buds with the quantity of blossoms and fruit later in the spring and summer.

At the end of the season, the resulting data regarding the hardiness of 65 varieties were compared with information provided by seven district horticulturists of the British Columbia Department of Agriculture Extension Service.

All observations and evaluations were recorded on a score basis of 0 to 10, 0 being used to indicate complete killing of the tree or part of the tree and 10 being used to indicate no apparent injury. However, the detailed scores for the thousands of trees involved are much too extensive for presentation in their entirety in this paper. Furthermore, mathematical averages would produce erroneous figures for the following reasons:

The plantings both on the Station and in grower orchards, from which data were obtained, varied very widely as to age of tree, previous year's crop, soil, moisture supply, cover crop, fertilizer and exposure to severe winter temperature. Most important of all, every orchard varied in the list of varieties represented. To give a simple example, the Vedette peach is a comparatively hardy variety, while J. H. Hale is tender. In an orchard in one of the most favoured districts J. H. Hale received an injury score of 7. In this orchard there were other comparable varieties but no Vedette. Again, in an orchard in one of the districts where injury was more severe, Vedette received a score of 4; but, although there were comparable varieties in this orchard, there were no J. H. Hale. It is obvious that, if figures such as these were used to arrive at mathematical averages, serious inaccuracies would result.

With the above facts in mind, the following procedure was adopted in ascertaining the comparative hardiness of fruit varieties:

In each orchard the hardiness of each variety was determined on the basis of whether the variety was hardier or more tender than other varieties of similar age growing under similar cultural conditions. Thus, to revert to the example previously given, in the J. H. Hale orchard there were comparable Rochester trees receiving a score of 9 and in the Vedette orchard there were comparable Rochester trees receiving a score of 2. When the results from these two orchards and many others were compared, it became evident that Vedette was hardier than Rochester and Rochester was hardier than J. H. Hale.

Similar procedures were followed to ascertain the influence on winter injury of such factors as age of tree, amount of previous crop, rootstock and framework stock.

SUMMARY OF OBSERVATIONS

Forms of Injury

Where root injury was experienced several degrees of damage could be distinguished. In the least severe cases only small feeding roots were killed. These trees recovered rapidly, showing only delayed development of foliage in the spring. In the most severe cases all sizes of roots were killed. These trees showed little life in the spring and died rather early in the season, with the coming of hot weather. Between these two extremes there were different degrees of root injury, the trees showing delayed development and later making recovery in relation to the extent of damage. In the larger roots the upper surface was frequently the more severely affected. Injury to the roots often extended to a depth of at least 12 inches.

Crown injury, where it occurred, was often very severe and sufficient to kill the tree. The injury was frequently at or near ground level and associated with the bud-union of the tree, sometimes extending upwards, sometimes downwards and sometimes in both directions from that point, involving both rootstock and scion variety.

Trunk injury took the form of damage to the bark, cambium and wood conducting tissues, but the cambium appeared to be hardier than bark or wood tissues. There was sunscald, bark- and wood-splitting and bark-lifting. Sunscald often occurred on the south and south-west sides and bark-lifting often on the north side of the tree. Sunscald injury to the trunk was accompanied frequently by a weakened or dying condition of the upper portions of that side of the tree. In cherry, when the outer wood conducting tissues of trunk and framework were injured, but the cambium remained alive, severe wilting of portions of the tree head occurred, but most trees recovered later when new conducting tissue had been formed by the live cambium. On the other hand, apple and pear trees injured in wood to a similar extent did not show this wilting condition.

Crotch and limb injury was frequent, bark, cambium and wood tissues being involved. Some large limb injury, particularly of apple, was in the form of sunscald, facing south-west. Where large limb injury was severe there was often heavy sucker growth from below the injured area.

Small limb and twig injury was commonly found, particularly in the apple variety Rome Beauty and in almost all peach trees. This usually involved complete killing of the twig.

Killing of fruit-buds was extensive, especially on peaches, apricots and Japanese plums.

Influence of Kind of Fruit on Winter Injury

With respect to tree injury, peaches were most tender and apples most hardy. Many plums especially Japanese varieties proved tender, but the Italian prune and several European varieties of plum were less injured than peaches, apricots and cherries. Pears were more hardy than most stone fruits, but less hardy than apples.

Fruit-bud killing was very general in peaches, apricots and Japanese plums, the 1950 crop of these fruits being very light indeed. Cherry and Italian prune buds withstood the low winter temperatures much better. Pear buds proved fairly hardy, although many fruit-spurs of the Bartlett variety suffered serious injury. There was comparatively little bud killing in apples, even in districts where tree injury was extensive.

Influence of Variety of Fruit on Winter Injury

Apple. With respect to tree injury the apple varieties examined can be placed in five groups: Crimson Beauty, Duchess, Haralson, Hyslop, Transcendent and Yellow Transparent proved very hardy; in the next group were McIntosh, Red Astrachan, Snow, Spartan and Wealthy; more severely injured than these were Delicious, Jubilee, Rome Beauty and Winesap; still more tender were Golden Delicious, Grimes Golden, Jonathan and Spitzenburg; the most tender group consisted of Newtown and Stayman.

Apricot. The most interesting feature of winter injury of apricot was that the varieties grouped themselves quite differently with respect to bud hardiness and tree hardiness. With respect to fruit-bud survival, Reliable, Rose and Tilton were hardiest; next in order came a group comprising Blenheim, Old Moorpark, Riland and Royal; more severely injured than these were Leslie, Perfection and Wenatchee Moorpark; the most

Cherry Seedling S-9-10

Van Cherry

FIGURE 1. Comparative hardiness of two cherry seedlings of the same age in the same orchard. Seedling S-9-10 was practically killed by the low temperatures of the winter of 1949-50, whereas the original tree of the Van variety was uninjured and bore a full crop in 1950. (Photos taken on the Summerland Experimental Station, June 1950).

FIGURE 2. Golden Jubilee and Vedette varieties of peach compared for hardiness at Okanagan Centre, B.C. The tenderer variety, Golden Jubilee, is shown at the white stake to the left of the picture. Note extremely sparse foliage, the result of severe winter injury to trunk and frame during winter of 1949-50. (Photo taken June 1950.)

FIGURE 3. Example of greater hardiness in 1949-50 of young as compared with older Elberta peach trees. The 2-year-old tree in centre is alive and healthy, whereas the 10-year-old trees have been completely winter killed. (Photo taken at Osoyoos, B.C., June 1950.)

bud-tender of the varieties examined was Kaleden. With respect to tree injury the least injured group was Kaleden, Reliable, Riland, Rose and Wenatchee Moorpark; next in order was Perfection and next to Perfection was Old Moorpark; the most tender group consisted of Blenheim, Leslie, Royal and Tilton.

Cherry. In fruit-bud hardiness Lambert, Royal Ann, Star and Van came in the group with least injury; these were followed by Bing, Black Tartarian and Deacon; Black Republican and Sparkle were more tender than any of the foregoing varieties. In tree hardiness Lambert and Van were best (Figure 1); next in order was Star; Bing, Deacon and Royal Ann were somewhat less hardy; the most severely injured group consisted of Black Republican, Black Tartarian and Sparkle.

Peach. Results with this fruit were less clear-cut than with apple, apricot and cherry. In general, however, the varieties appeared to place themselves in four groups with respect to fruit-bud hardiness. The best group included Halehaven, Muir, Superior and Vedette; next were Fisher, Redhaven, Rochester and Veefreeze; more severely injured were Elberta, Golden Jubilee, Red Elberta, Spotlight and Veteran; the most tender group consisted of Glamar, J. H. Hale, Solo, Valiant and Vanguard. In tree hardiness there also were four groups. In the first group were Fisher, Halehaven, Mikado, Redhaven, Solo, Spotlight, Superior, Vedette and Veteran; Valiant was somewhat less hardy than these; still less hardy were Golden Jubilee, Rochester and Vanguard (Figure 2); in the most tender group were Elberta and J. H. Hale.

Pear. In fruit-bud hardiness there were three varieties in the first group, Anjou, Flemish Beauty and Winter Nelis; these were followed by Clapp Favorite and Lincoln; the least hardy group consisted of Bartlett, Bosc and Clairgeau. In tree hardiness also, Anjou, Flemish Beauty and Winter Nelis were in the first group; Old Home appeared also to belong to this group, although its responses were rather variable; the second group consisted of Bartlett, Bosc, Clairgeau, Clapp Favorite and Lincoln; Farmingdale was more severely injured than any other variety examined.

Plum. In fruit-bud hardiness Quackenboss and Red Coat were best; in the next group were Italian Prune and its early strains, De Maris and Greata; less hardy than these were Bradshaw and Peach Plum; the most severely injured group consisted of June Blood and Santa Rosa. In tree hardiness Quackenboss and Red Coat were again in the first group, and Italian and its early strains in the second group; Bradshaw, June Blood and Peach Plum comprised the third group; Santa Rosa was the most tender variety examined.

Influence of Age of Tree and Amount of Crop on Winter Injury

Usually those trees which bore heavily in 1949 were much more susceptible to injury than those which did not bear heavily that year. This was particularly noticeable in apples.

Peach trees over 12 years old were much more tender than younger trees (Figure 3); on the other hand many apricot trees 10 to 30 years old were as hardy or hardier than trees from one to 9 years of age. Young sweet cherries up to about 15 years of age were hardier than either peaches or apricots, but old cherry trees were in many cases very severely injured, and trees over 35 years were often killed even in favoured areas. Young Italian prune trees up to 10 years of age proved hardier than old trees of this variety. Pear trees under 10 years of age were not noticeably hardier than older trees of the same variety. In the coldest areas apple trees over 20 years old were much less hardy than younger trees.

Influence of Root and Framework Stocks on Winter Injury

There was some evidence that apricot trees on apricot rootstocks were hardier than apricot trees on peach rootstocks. In several instances trees died because of tenderness of stock rather than scion variety. Seedlings of the California variety, Lovell, have been by far the most widely used peach rootstock in British Columbia. There was evidence that old peach trees were injured severely where the crowns were exposed to the very low winter temperatures, and, moreover, young trees of the Lovell variety,

PRELIMINARY REPORT ON THE TREATMENT OF EUROPEAN FOULBROOD OF HONEYBEES WITH ANTIBIOTICS[1]

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[Received for publication August 30, 1951]

European foulbrood (EFB) is a disease of young larvae of the honeybee. Its cause is still uncertain and its gradual increase in the United States and Canada in the past few years has made it a serious problem. The standard methods of control, such as requeening with Italian stock, dequeening and leaving queenless for a time or making colonies stronger, have failed to control EFB in many cases (2, 4). The sulpha drugs so enthusiastically and recklessly adopted by beekeepers as a cure for American foulbrood are without effect on EFB (1, 3, 5).

During the past few years reports from northern Saskatchewan have indicated a sharp increase in the number of colonies affected by EFB and in some cases a serious loss of colonies, especially in yards where bees are gassed at the end of the season and new packages installed every spring. Representations therefore were made by the Canadian Beekeepers' Council to the Dominion Department of Agriculture to initiate studies on the control of this disease. Such a project was accordingly established with Science Service, the Apiary Branch of the Saskatchewan Department of Agriculture and a commercial beekeeper, B. Hamilton, Sylvania, Sask., who kindly supplied the colonies. In this paper are presented the results of the experiments conducted in 1951 on the use of antibiotics for the prevention of infection and the cure of infected colonies.

EXPERIMENTAL METHODS AND RESULTS

All the colonies used in these experiments were infected with EFB to a greater or lesser extent as indicated in the Appendix. In all, 53 colonies were used.

Prevention by feeding antibiotics

Twenty-five colonies were selected for this purpose, each treatment being replicated five times. Ideally the colonies should have had no disease and should have been filled with dry, empty combs. However, this was not possible in a commercial yard so that one empty comb and/or one containing eggs was marked and placed at the centre of each colony and used for observation. Obviously combs containing even young larvae could not be used in this experiment as these larvae might already have been infected. Each colony was fed one gallon of 50 per cent sugar syrup containing EFB inoculum (10–15 macerated infected larvae); each marked comb was also sprayed with this suspension. The antibiotics used (grams per gallon syrup) were: streptomycin 0.6, chloromycetin 0.5, aureomycin and terramycin 0.25 each. The colonies were all fed at the same time, the feedings extending over a period of 2 weeks. Examinations for disease

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TABLE 1.—PREVENTION OF INFECTION OF MARKED CLEAN COMB WITH EFB BY FEEDING ANTIBIOTICS TO NATURALLY INFECTED COLONIES*

Treatment	Examination (days)	Colonies				
Check		U1	U2	U4	U11	U13
	7	5 (0, 0) 6	2 (0) 5	135 (9, 0) 26	12 (0) 3	0 (0, 0) 4
	14	17 (18, 11) 7	0 (0) 0	99 (213, 35) 153	40 (70) 62	0 (2, 1) 1
	29	16 (9, 5) 0	0 (4) 0	35 (40, 50) 57	70 (38) 44	0 (0, 0) 0
Streptomycin		U6	U8	U19	U21	U21A
	7	0 (0) 0	0 (0) 14	1 (0) 1	9 (0, 1) 9	6 (0, 0) 2
	14	0 (0) 0	3 (0) 5	0 (0) 0	5 (2, 5) 3	2 (1, 1) 0
	29	0 (0) 0	0 (0) 0	0 (0) 0	4 (0, 0) 0	0 (0, 0)
Chloromycetin		U3	U15	U18	K1	K4
	7	0 (11, 0) 5	1 (0) 0	2 (0, 4) 0	5 (0) 4	0 (0) 0
	14	12 (5, 7) 3	1 (0) 0	0 (0, 0) 0	4 (6) 5	6 (2) 4
	29	1 (2, 0) 0	0 (2) 0	5 (1, 2) 0	9 (2) 14	0 (0) 0
Aureomycin		K3	K11	K11A	K13A	K14
	7	2 (0, 0) 23	10 (0) 20	0 (0) 2	0 (0) 0	0 (0) 0
	14	15 (7, 3) 14	55 (53) 58	1 (2) 2	0 (0) 0	0 (0) 0
	29	0 (0, 0) 0	22 (10) 40	1 (0) 2	0 (0) 0	0 (0) 0
Terramycin		U22	K2	K5	K10	K13
	7	0 (0) 0	0 (0) 15	2 (0) 13	0 (0) 0	0 (0) 0
	14	0 (0) 0	3 (0) 9	3 (2) 8	1 (3) 0	0 (0) 0
	29	1 (1) 0	2 (3) 2	0 (0) 0	0 (0) 1	0 (0) 0

* Numbers represent infected larvae in each comb given; only one comb on each side of the marked clean comb or combs (in brackets) being included in this table. At zero time all the bracketed combs were free from disease; the remaining combs were all infected to a slight degree as indicated in the text.

were made at the intervals given in the tables. Emphasis in examination was placed of course on the marked, originally disease-free comb. However, all the remaining combs in every colony were also examined as a further check on the development of the disease. As will be noted, the results for the marked combs (in brackets) and only those adjacent to these are given in Table 1. In effect the adjacent combs serve as a duplicate of the therapeutic trials reported in Table 3, since they contained infection at the beginning of the experiment. The remaining combs in the colonies presented much the same picture as those included in Table 1.

It will be observed that all bracketed combs in four colonies of the check series showed infection; the comparatively clean colony U13 may have been particularly strong and the diseased material removed.

With streptomycin, not one of the marked combs showed any sign of disease at the last examination; a few infected cells appeared in colonies U21 and U21A. The antibiotic also seems to have held the disease in check in the adjacent combs as well. Terramycin was almost as effective as streptomycin, and though aureomycin gave good results in three colonies, two colonies (K3 and K11) showed fairly extensive infection. With chloromycetin, however, four colonies showed marked comb with disease at the last observation.

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	14	12 (5, 7) 3	1 (0) 0	0 (0, 0) 0	4 (6) 5	6 (2) 4
	29	1 (2, 0) 0	0 (2) 0	5 (1, 2) 0	9 (2) 14	0 (0) 0
Aureomycin		K3	K11	K11A	K13A	K14
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	14	15 (7, 3) 14	55 (53) 58	1 (2) 2	0 (0) 0	0 (0) 0
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	7	0 (0) 0	0 (0) 15	2 (0) 13	0 (0) 0	0 (0) 0
	14	0 (0) 0	3 (0) 9	3 (2) 8	1 (3) 0	0 (0) 0
	29	1 (1) 0	2 (3) 2	0 (0) 0	0 (0) 1	0 (0) 0

* Numbers represent infected larvae in each comb given; only one comb on each side of the marked clean comb or combs (in brackets) being included in this table. At zero time all the bracketed combs were free from disease; the remaining combs were all infected to a slight degree as indicated in the text.

were made at the intervals given in the tables. Emphasis in examination was placed of course on the marked, originally disease-free comb. However, all the remaining combs in every colony were also examined as a further check on the development of the disease. As will be noted, the results for the marked combs (in brackets) and only those adjacent to these are given in Table 1. In effect the adjacent combs serve as a duplicate of the therapeutic trials reported in Table 3, since they contained infection at the beginning of the experiment. The remaining combs in the colonies presented much the same picture as those included in Table 1.

It will be observed that all bracketed combs in four colonies of the check series showed infection; the comparatively clean colony U13 may have been particularly strong and the diseased material removed.

With streptomycin, not one of the marked combs showed any sign of disease at the last examination; a few infected cells appeared in colonies U21 and U21A. The antibiotic also seems to have held the disease in check in the adjacent combs as well. Terramycin was almost as effective as streptomycin, and though aureomycin gave good results in three colonies, two colonies (K3 and K11) showed fairly extensive infection. With chloromycetin, however, four colonies showed marked comb with disease at the last observation.

Prevention by spraying antibiotics

Unfortunately only one colony was available for each antibiotic in this trial. Again one or two empty combs or combs with eggs were used. Each was sprayed with inoculum followed by the antibiotic and then placed at the centre of the colony. A 1 per cent solution of streptomycin and chloromycetin was prepared and a 0.5 per cent solution of aureomycin and terramycin; about 50 ml. of solution was used per comb. Although the results obtained can only be considered suggestive, it is worthy of note (Table 2)

TABLE 2.—PREVENTION OF INFECTION OF MARKED CLEAN COMB WITH EFB BY SPRAYING WITH ANTIBIOTICS (EFB INOCULUM)*

Examination (days)	Antibiotic			
	Streptomycin**	Chloromycetin**	Aureomycin	Terramycin
	(Colony X)	(U17)	(K7)	(K8)
7	0, 0	0, 4	0	0
14	0, 0	0, 2	0	0
29	0, 0	14, 6	0	0

* Expressed as number of larvae infected with EFB in originally empty comb or comb with eggs.
** Two combs were available in these colonies.

TABLE 3.—EFFECT OF FEEDING ANTIBIOTICS TO COLONIES WITH VARYING DEGREES OF INFECTION WITH EFB*

Treatment	Examination (days)	Colonies				
Streptomycin		H3A	H6	H9	H13	H19
	0	> 10	> 10	< 1	> 10	2
	6	3	7	< 1	12	< 1
	13	2	3	0	4	< 1
	28	0	0	0	0	0
Chloromycetin		H2	H6A	H6B	H15	H16
	0	< 1	2	> 10	> 10	2
	6	8	8	11	43	4
	13	60	12	10	46	3
	28	40	12	7	52	3
Aureomycin		H3	H4	H5	H5A	H8
	0	> 10	< 1	2	2	< 1
	6	21	1	5	< 1	0
	13	36	1	3	< 1	0
	28	30	3	4	1	0
Terramycin		HYA	H10	H15A	H18	F6
	0	> 10	< 1	< 1	> 10	< 1
	6	2	< 1	0	0	0
	13	0	0	0	0	0
	28	2	0	0	0	0

* Expressed as average numbers of infected larvae per comb (each colony contained 5 to 8 combs).

that the combs sprayed with streptomycin, aureomycin and terramycin showed no evidence of disease whereas those treated with chloromycetin contained infected larvae. The check combs sprayed with inoculum have been mentioned earlier as being infected (Table 1).

Cure by feeding antibiotics

Twenty colonies in all stages of infection were available for this experiment. They were divided so that each set of five in a treatment contained slightly and heavily infected colonies. No inoculum was given to these colonies by agreement with the owner; and the antibiotics were fed at the same rate as in the prevention tests. The number of infected cells was determined for every comb in each colony but only the averages are given in Table 3. Streptomycin reduced infection to zero in every instance, even in three badly infected colonies, as did terramycin. Aureomycin was not particularly effective and chloromycetin decidedly not; in fact it appeared to increase the severity of the disease in three colonies.

Cure by spraying antibiotics

As with the experiment in prevention by spraying, only four colonies were available, one for each antibiotic. Combs containing infected larvae were sprayed with antibiotic, marked and placed in the centre of each colony. The results given in Table 4 show that this procedure was not very effective in curing the comb although aureomycin might be considered promising. Once more chloromycetin seemed harmful.

TABLE 4.—EFFECT OF SPRAYING ANTIBIOTICS ON COMB CONTAINING LARVAE INFECTED WITH EFB*

Examination (days)	Antibiotic			
	Streptomycin colony (K6A)	Chloromycetin (T8)	Aureomycin (K7A)	Terramycin (T20)
0 – 4	30	13	9	58
7	13	11	3	35
14	7	28	2	7
29	19	67	0	16

* Expressed as number of larvae infected with EFB in sprayed comb.

DISCUSSION

The results of the experiments considered above show that feeding certain antibiotics as preventives or as cures holds some promise in controlling European foulbrood. Spraying clean material as a prophylactic measure also offers hope of success. If it is true that EFB is caused by a non-spore-forming organism which the antibiotics can inhibit or kill by contact (as opposed to their general ineffectiveness against spores such as those of AFB) it should be less difficult to control EFB than American foulbrood (AFB), especially by spraying the hive and its contents. The antibiotic need not be 100 per cent effective as long as it keeps the disease

in check until the colony has built up strength to clean the disease out or until the honey-flow begins, at which time the disease frequently disappears. Obviously further work is required to corroborate the above results, to determine the optimum antibiotic levels, and the most effective time for, and method of application of, the antibiotic. The choice of antibiotic will depend on its toxicity, availability and cost. Terramycin is relatively non-toxic; streptomycin perhaps only slightly more so; but in the amounts used their effect would be negligible, especially in the honey supers. These compounds are more expensive than sulpha drugs but if 0.5 gram, costing about $1.00, will save a colony and its honey crop worth up to $30.00 to $40.00, the investment would be justified.

SUMMARY

Streptomycin and terramycin, and to a lesser extent aureomycin, when fed to colonies or sprayed on clean comb, effectively prevented development of EFB supplied naturally and artificially. These same substances also reduced infection markedly when fed to diseased colonies but not when sprayed on diseased comb. The antibiotic chloromycetin was not useful in these connections and in fact appeared to increase severity of the disease.

ACKNOWLEDGMENTS

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APPENDIX

Degree of infection of colonies used.

Heavy infection—10 or more cells per comb.

H3, H3A, H4A, H6, H6B, H13, H15, H18
K2, K6A
T8, T2D
U18

Light to moderate infection—3 to 5 cells per comb.

H2, H4, H8, H9, H10, H15A
K1, K3, K4, K5, K7, K7A, K8, K10, K11, K11A, K13, K13A, K14
U1, U2, U3, U4, U6, U8, U11, U13, U15, U17, U19, U21, U21A, U22
F6, X

CHANGES IN SPECIFIC GRAVITY OF EGGS DURING THE LAYING YEAR[1,2]

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Specific gravity of the whole egg has been shown by Olsson (6) to be a very good indication of the percentage of shell. Munro (4, 5) later used this method and found that specific gravity was related to both hatchability and livability of the chicks to three weeks of age. The eggs used in these tests were collected over a period of five weeks. More recently Godfrey and Jaap (1) confirmed these results in a trial which was continued over a longer period of time. These reports have been chiefly concerned with the relationship existing between specific gravity and hatchability.

It is well known that the percentage shell decreases as the production year advances. One method of measuring changes in percentage shell without destroying the value of an egg, from either a market or incubation standpoint, is by means of specific gravity. Gutteridge and Novikoff (2) in their report on the effect of thyroprotein on shell strength plot the mean specific gravity of eggs according to treatment covering a period of 29 weeks (January 4-July 26). Godfrey and Jaap (1) while studying relationships between estimates of shell quality list the average specific gravity of eggs for their two strains of New Hampshires for periods of 35 and 15 weeks (December 1-September 2 and April 28-August 15). In both reports, the specific gravity decreased throughout the trials but whether or not these trends were significant was not determined.

It seems of value to record the authors' findings relative to the changes in specific gravity throughout a laying year. These data constitute a portion of a study on egg quality over a 2-year period.

MATERIALS AND METHODS

The first year's test (1948-49) was with a group of 199 Barred Plymouth Rock pullets which were housed at the commencement of production on the ground floor of a two-storey insulated laying-house. The pen used (Pen A) was 25 feet by 30 feet and had a combination slot-shaft type of ventilation. The second group (1949-50) comprised 367 Barred Plymouth Rock pullets. The date of housing was approximately the middle of September for both years. They were housed at the onset of production. Pen A was again used for 200 of these pullets and two adjoining pens (B and C), each 20 feet by 30 feet, were used for the remaining 167 birds. Pens B and C each contained 150 pullets. Data were collected on all the pullets in Pen A and B but on only 17 in Pen C as the remaining 133 birds were a separate strain. No differences in production or specific gravity were found between pens. Each year's birds were composed of approximately equal numbers of 4 weekly hatches selected at random from the regular breeding stock and were housed for the duration of the test.

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[2] Contribution from the Poultry Department, University of Saskatchewan, Saskatoon, Saskatchewan.

[3] Associate Professor and Professor.

The pullets were fed a breeder's mash ad lib. throughout the trial and whole grain was fed twice a day in quantities regulated to equal the mash consumption. A calcium-bearing grit was available to the birds at all times.

All the birds were trapped on a 5-day week and every tenth recorded egg was tested for specific gravity. The salt solutions were made up with class intervals of 0.004. These were kept in covered beakers in a cool room and were tested each week. The eggs were dipped into solutions the morning following production and the egg was considered to have a specific gravity equal to the solution in which it just floated. Observations were recorded from mid-September until the end of July for each of the two years. A total of 6,166 eggs were used in this study.

DISCUSSION OF RESULTS

The specific gravity of each tenth recorded egg for each group of birds is summarized and presented in Table 1.

The initial specific gravity for both series is almost identical. This is to be expected since no direct selection was made in the parent stock for this factor aside from the discarding of those birds which laid poor quality shells during their pullet year. As the season progressed the specific gravity decreased at fairly uniform rate for both series. However, the average rate of decrease was somewhat greater for the 1948-49 birds than for those of 1949-50 as indicated by a comparison of the 150th recorded egg for both years. This is illustrated graphically in Chart 1. Even though there is a difference in the specific gravity of these groups, the means for the two years are very similar.

The most pronounced decrease in specific gravity occurred between the 130th (or 182nd egg when transposed to a 7-day week, see Chart 1) and the 140th egg for the 1948-49 group and between the 60th (84th) and 70th

TABLE 1.—SUMMARY OF SPECIFIC GRAVITY FOR EACH RECORDED EGG—BOTH YEARS

Egg Number		1948-49		1949-50	
Recorded (5-day trap)	Estimated (7-day basis)	No. of eggs	Specific Gravity	No. of eggs	Specific Gravity
10	14	199	1.0835	367	1.0830
20	28	197	1.0836	358	1.0821
30	42	194	1.0829	350	1.0810
40	56	191	1.0824	345	1.0805
50	70	188	1.0814	337	1.0794
60	84	183	1.0805	326	1.0786
70	98	182	1.0792	312	1.0772
80	112	172	1.0783	284	1.0772
90	126	167	1.0763	261	1.0769
100	140	157	1.0753	226	1.0765
110	154	155	1.0743	185	1.0760
120	168	141	1.0730	145	1.0759
130	182	130	1.0730	100	1.0755
140	196	95	1.0706	65	1.0751
150	210	67	1.0696	33	1.0739
160	224	34	1.0693	—	—
Average		2453	1.0785	3694	1.0789

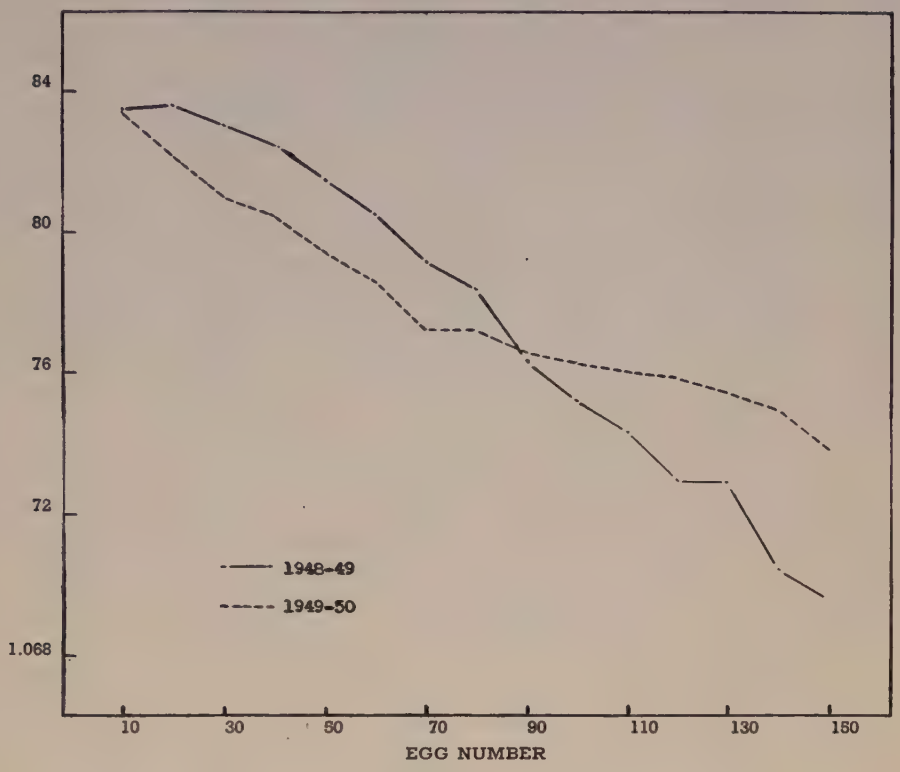

CHART 1. Average specific gravity for each recorded egg.

(98th) egg for the 1949-50 group. In the former this relatively sharp decline was preceded by a sustained level of specific gravity and, in the latter, was followed by a sustained level. The disparity of these observations cannot be explained on a seasonal basis. This is substantiated by the fact that four weekly hatches each year were involved and also age at sexual maturity and rate of production were not the same for all birds. If it is assumed that a fairly uniform decline is the normal situation, then a possible explanation is that these sustained levels are chance variations. This seems a logical basis since one-half of the sudden drop in each case is approximately equal to the average decrease from one recorded egg to the next.

The data in each series were tested by variance analysis to determine whether or not the decrease in specific gravity throughout the test period was significant. In both cases, the F value was beyond the 1 per cent point, indicating that the decline was not due to chance alone.

A few birds in each series laid one or more eggs beyond those recorded in Table 1 but because of their small numbers were not included. While the data presented suggest that specific gravity decreases as the individual bird's production advances, these data cannot be interpreted as being strictly seasonal in effect. Such factors as time of sexual maturity, intensity of production and persistency must be considered. By rearranging the data of the 1949-50 series on a monthly basis it is possible to determine the seasonal effect upon specific gravity. The data are presented in Table 2.

TABLE 2.—SUMMARY OF SPECIFIC GRAVITY, BY MONTHS, 1949-50.

Month	No. of Eggs	Specific Gravity
September	33	1.0830
October	150	1.0829
November	248	1.0810
December	367	1.0825
January	339	1.0809
February	417	1.0816
March	581	1.0761
April	478	1.0793
May	467	1.0776
June	382	1.0749
July	251	1.0756
Average	3713	1.0789

The pullets were housed in mid-September when production was just commencing. With only a 5-day trapping week, not many 10th eggs were recorded for this month. The average specific gravity was 1.0830 which is the same as for the 10th eggs of the same group. The decline in specific gravity, month by month, was evident throughout the year though not always consistent. A sudden drop occurred during March which coincided with the peak of production. During this month, the rate was 69.52 per cent and on the average each bird produced slightly over two eggs for testing. The relatively high rate of production may have had some bearing upon this drop. The data of Godfrey and Jaap (1), in which one egg in each six was selected at random for testing, also show a consistent decline for the test period (December 1-September 2) for their Ohio New Hampshires though their range was somewhat greater than the one reported here. Gutteridge and Novikoff (2) determined the average specific gravity for each group by testing all eggs for one week in four. The decrease in specific gravity was consistent throughout the trial and was comparable in range to our 1949-50 series. The decline in specific gravity which is interpreted as meaning a lowering of the percentage shell agrees with Morgan (3).

A variance analysis of the data grouped according to the month in which the eggs were laid yielded an F value of 68.7 which is well beyond the 1 per cent point. This highly significant value means that the decrease in specific gravity throughout the laying year is not due to chance but rather to a significant lowering of the percentage shell.

SUMMARY

Specific gravity of the egg has been used as a measure of per cent shell. Results based on observations from 6,166 Barred Plymouth Rock eggs over a 2-year period (1948-50) indicate that there is a significant decline in specific gravity during the test period (mid-September to the end of August) as the production of each bird advances.

A comparison of the eggs laid each month throughout the 1949-50 year shows that as the season progresses, the specific gravity decreases at a significant rate.

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THE EFFECTS OF WEED AND INSECT SPRAYS ON SPRAYING EQUIPMENT MATERIALS

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While some information is available from the manufacturers of various herbicides and insecticides as to their probable action on metals in concentrated form, there is little to indicate the probable effect of these sprays, as used in the field, on the various parts of the spray rig. It was with this in mind that the Department of Agricultural Engineering of the University of Manitoba conducted experiments to determine the effects of the common weed and insect sprays on materials which might be used in the manufacture of spraying equipment.

Preliminary experiments were conducted in April 1949, using 2-4-D in its three common forms, also Chlordane and Toxaphene, together with 18 different materials. The results of these tests were reported in a mimeographed circular in May 1949. A more extensive set of tests was planned for the spring of 1950 but was delayed until December because of the flood. In this second set of experiments were included the more important chemicals used in previous experiments, together with certain newer ones. Twenty-four different materials were used, including metals, non-metals and various forms of metal coatings. These were subjected to the action of 6 different solutions as well as tap-water.

MATERIALS

List of Solutions

1. Tap water	
2. 2-4-D Ester (1 lb. acid equivalent in 4 gal. water)	Weed Sprays
3. Sodium T.C.A. (1 lb. in 1 gal. water)	Weed Sprays
4. Polybor chlorate (2 lb. in 1 gal. water)	Weed Sprays
5. Aldrin (1 oz. acid equivalent in 2½ gal. water)	Insect Sprays
6. Dieldrin (1 oz. acid equivalent in 2½ gal. water)	Insect Sprays
7. Chlordane (1 lb. acid equivalent in 4 gal. water)	Insect Sprays

Description of Materials Used

Metals and Metal Coatings

1. Black, iron—$\frac{1}{8}'' \times \frac{3}{4}''$
2. Canada plate.
3. Aluminum sheet.
4. Armco aluminized sheet steel (Al, coating about .001 thick)
5. Aluminum pipe ($\frac{3}{4}''$) with brass fitting threaded in.
6. Galvanized iron sheet—Hot dipped and rolled.
7. Galvanized iron plate—Hot dipped.
8. Galvanized pipe ($\frac{1}{2}''$) with brass fitting threaded in.
9. Zinc sheet.
10. Tinned iron, painted one side with lithographers' paint. (Material from 1 qt. anti-freeze cans).
11. Copper sheet.
12. Brass sheet.
13. Stainless steel sheet.

Metals with Non-metal or Paint Coatings

14. Armco asbestos bonded steel sheet. (Galvanized sheet covered with a coating of asphalt impregnated asbestos felt applied with the zinc in a molten state.)
15. Steel sheet with finish "X" as used on Kromer spray boom.

16. Steel sheet treated with Bonderite 160 (Parker Rustproof Company) (Zinc and Iron Phosphate coating approx. 150 mg./sq. ft.). Brush painted with Permolite No. 40 Prime (a pigmented modified phenolic air dry coating.)
17. Same as above but with Permolite No. 11 cold set compound (a modified phenolic resinoid compound) applied in addition to the Permolite No. 40.
18. Steel sheet treated with Bonderite 1000 (Parker Rustproof Company) (Iron phosphate coating 40–80 mg./sq. ft.). Brush painted with Permolite No. 40 Prime.
19. Same as above with Permolite No. 11 applied in addition.
20. Steel sheet with general purpose paint Coating (Dorman Simplex Sprayer Company).
21. Steel sheet with acid resistant paint coating. (Dorman Simplex Sprayer Company.

Non-metals

22. "Uscolite" pipe (1") with screwed brass fitting. (U.S. Rubber Company) (thermoplastic resin and synthetic rubber).
23. Rubber water hose 1/2".
24. Rubber sprayer hose ¾" (as used on low pressure weed sprayers by one manufacturer, but similar to water hose).

METHODS

Six 3-gallon earthenware crocks were used as containers for the different spray mixtures. All test pieces were suspended by cotton twine at approximately equal distances apart around the inside of each crock, at such a height that half of each test-piece was below water, except for the sections of rubber hose which were completely immersed. The sheet metal test-pieces were in the form of strips varying from 1/2" to 1" wide and from 3" to 6" long, depending upon material available. The possibility of electrolytic action between a brass nozzle and aluminum or galvanized spray boom was tested by using short pieces of brass tubing threaded into short sections of these materials.

The possibility of interaction of the various samples in the same solution was considered also, but the additional equipment necessary to guard against this factor was not thought to be justified.

To prevent the settling of some spray solutions, agitation was provided by compressed air through a ring of copper tube in the bottom of each crock directly below the test pieces. Six very small holes allowed for a uniform distribution of air. The amount of air to each tube was controlled by a stopcock. The purpose of the agitation was twofold: to prevent settling of some spray mixtures, and to accelerate the reaction between the materials and solutions by additional aeration. Agitation was provided for an average of 6 to 8 hours each day. Half of each sample only was immersed in the spray solution, to show if possible the effects of the two different conditions.

The concentration of the spray mixtures was taken so as to be well above the average strength at which they would most likely be used.

The duration of the test was approximately 7 weeks. Near the end of this time very little reaction was observed. One or two samples were added to the test after it had been in operation for some time. These are noted in the results.

After the preliminary tests in 1949 and before discarding the solutions a portion each of the 6 spray mixtures was poured into cans of 3 different kinds and set away in the storeroom for later observation with the hope

that they might provide some small amount of additional information. After 21 months these were cleaned out, cut into strips and examined carefully. The results of this extended test are given in Table 2.

RESULTS AND OBSERVATIONS

Description of the changes in the appearance of the samples during the test period proved to be the most difficult task. These are outlined in Table I. Observations were made daily for the first few days; then the intervals gradually lengthened to two or three days and finally twice each week. Little change was observed after about three weeks. After the test was completed the samples were allowed to dry thoroughly.

After drying, a part of one or both sides of each piece was scraped, and then cleaned with a wire brush to remove the deposit which usually formed at or above the water line particularly with TCA and Polybor chlorate. After cleaning further observations were made. Where sheet erosion of the specimens occurred the amount was measured with a micrometer. Where pitting of the surface occurred an approximate measurement of the depth of pits was obtained by a calibrated microscope focused first on the bottom of the pits and then on the surface. Although loss of weight is often used as the principal measure of erosion in many test specimens it was felt that it would have less value here than the methods used. Thickness of materials is given in millimeters in most cases for ease of comparison.

In the preliminary tests rubber hose sections were tested under hydrostatic pressure. Results indicated that the appearance and "feel" of such samples is sufficient. Materials used in the first set of tests but not in the second are included and marked with an asterisk (*) where it is considered they would be of interest.

DISCUSSION AND SUMMARY

It will be noted that the only two samples showing no change in any solution were stainless steel, and Kromers' Finish "X". Aldrin, Dieldrin and 2-4-D Ester generally attack paints but not many metals. The action of polybor chlorate and T.C.A. is usually the reverse.

Little change was noticed in any of the samples after about 35 days.

Tap water was used mainly as a check but it attacked black iron and aluminum rather badly, and zinc to a lesser extent.

2-4-D Ester in general attacked only zinc in the metal group but was very hard on non-metallic coatings and materials such as rubber and plastics. Most paint coatings below water were gone after 16 days in Ester.

T.C.A. had relatively little effect on most paints but rusted all iron very badly. Zinc also was attacked quite seriously, while aluminum was worst of all. The aluminum sheet corroded through in about 30 days while the aluminum pipe was almost eaten through at the end of the test. Brass and copper sheet were attacked but little, but the air jets in the copper tube required frequent cleaning to operate at all.

Polybor Chlorate had relatively little effect on most metals and paints. Zinc, however, was attacked rather badly.

Aldrin attacked iron, zinc, and aluminum to some extent, also the asbestos and Permolite coatings, but not nearly as badly as 2-4-D Ester.

Dieldrin is similar to Aldrin in action but to a somewhat less extent.

Chlordane attacked metals such as iron, zinc, and aluminum, but has relatively little effect on most paint coatings.

(Continued on page 203)

TABLE 1.—EFFECTS OF SPRAY MIXTURES ON SPRAY RIG MATERIALS

Spray Mixture	Black Iron (3.07 mm.)	Canada Plate (.46 mm. thick)	Tinned Iron (.28 mm.)
TAP WATER	* (1.5) 10% rusted below water. Rust slowly increased. (53) Erosion on edges .0150 mm. thinner. Pits on flat surface .013 mm. deep.	(1.5) Rust on edges. (53) Approx. 40% of surface rusted below water. .0015″ (.0375 mm.) thinner under rust.	(53) Rust on edges only below water. Lithographers' paint on back of strip O.K.
2-4-D ESTER	O.K. (53) No rust or corrosion.	O.K. (53) No rust or corrosion.	(1.5) Lithograph paint loosened; tin O.K. (53) Tin O.K.; lith. paint peeled with finger nail.
SODIUM T.C.A.	(1.5) 5% rusted. (3) Badly rusted above water. (16) Very badly rusted. (53) Pits above water-line, .05–.15 mm. deep.	(1.5) Quite badly rusted all over. (16) Very badly rusted. (53) Surface minutely pitted, badly corroded above water .002″ deep. (.05 mm.).	(1.5) Edge only rusted. Paint O.K. (53) Iron eaten through on edge. Lithographed paint off above water, O.K. below.
POLYBOR CHLORATE	(1.5) O.K. (13) Slight rusting above water only. (53) Slight rusting above water on edges.	(1.5) O.K. (8) O.K. (53) Some rusting and pitting above water. O.K. below water.	(1.5) O.K. (13) O.K. (53) Lith. paint O.K. Some rusting above water and tin eaten away at water-line.
ALDRIN	(1.5) 5% rust below water. Progressive rusting similar to water. (53) Rust on edges and pitted below water 0.1 to .25 mm. deep.	(1.5) Rust on edges. (53) Rusted and pitted on edges below water; pits 0.1 to 0.2 mm. deep.	(1.5) O.K. (53) Tin and lith. paint O.K.
DIELDRIN	(1.5) 5% rust below water. Rusting same or slightly less than water. (53) Slight rusting at edges only.	(1.5) O.K. (53) Slight rusting above water and at one or two points below.	(1.5) Tin O.K. Paint very slightly loosened. (53) Slight rusting on edges below water, also on surface above water. Paint O.K. but probably slightly loosened.
CHLORDANE	(1.5) 5–8% rusted. (8) Quite rusty all over. More rust than in water. (53) Quite badly rusted all over, very shallow pits above water.	(3) Some rust. (8) Quite rusty all over. (53) Rusted all over especially on edges below water and on surface above water. Pits 0.1 mm. deep.	(1.5) Some rust on edges. (3) Quite rusty on edges. (53) Tin eaten away and rusted above water. Pits through iron below water. Pits 0.1–0.2 mm. deep.

* Figures in brackets indicate number of days after start of test.

TABLE 1.—EFFECTS OF SPRAY MIXTURES ON SPRAY RIG MATERIALS—*Continued*

Spray Mixture	Hot Rolled Galvanized Sheet (.45 mm.)	Hot Dipped Galvanized Plate (on test only for last 31 days) (2.2-2.25 mm.)	1/2" Galv. Pipe and Brass Fitting
TAP WATER	(1.5) rusting started below water. (16) Rusting through galvanizing. (53) Zinc off about 10% surface below water.	(1) O.K. (3) Very slight corrosion. (31) Zinc finely pitted below water. Pits too small to measure.	(1.5) Rust at joint between brass and galv. (3) Pipe darkened (53) Rusted at ends and at joint.
2-4-D ESTER	(1.5) Very black, deposit below water. (16) Blackened and corroded. (53) Below water .38 mm. Above water .45 mm. Most of zinc gone below water.	(1) O.K. (4) Discoloured. (10) Quite dark on one side. (31) Same as (10).	(1.5) Pipe and fitting badly discoloured below water. (3) Blackened and corroded below water. (53) Zinc appeared to be gone. .001" less diameter below water.
SODIUM T.C.A.	(1.5) Badly corroded. (16) Very badly corroded. (53) Slightly pitted at water surface. 0.1 mm. deep.	(1) Beginning to show reaction. (2) Corrosions started. (10) Badly corroded. (31) Badly corroded with tough white deposit but not pitted.	(1.5) Very badly corroded. (53) Both brass and zinc badly darkened and corroded.
POLYBOR CHLORATE	(1.5) Slightly discoloured at water-line. (4) Badly corroded below water. (53) Zinc loosened and scaled off in patches near water-line and above. (.077 mm. thinner).	No test.	(1.5) Slightly discoloured. (8) Pipe O.K. (53) Little change; slightly more pitted above water.
ALDRIN	(1.5) Some corrosion on surface. (53) About 40% of zinc gone below water.	No test.	(1.5) Galvanized discoloured, corrosion at joint. (13) Rust at joint. (53) A few pits below water and at threaded joint.
DIELDRIN	(1.5) Slight corrosion. (53) Some corrosion only, a film formed over zinc.	No test.	(1.5) Slight white corrosion. (53) No change.
CHLORDANE	(1.5) Darkened. (13) Somewhat corroded. (53) Zinc coating about 40% eaten off about water-line.	(1) O.K. (4) Very slight corrosion. (31) Zinc corroded slightly both above and below water.	(1.5) Badly corroded, also at joint. (3) Darkened. (53) Pipe darkened below water; little change.

TABLE 1.—EFFECTS OF SPRAY MIXTURES ON SPRAY RIG MATERIALS—*Continued*

Spray Mixture	Zinc Sheet (.47) mm.	Aluminized Sheet Steel (.62 mm.) (on test for last 10 days only)	Aluminum Sheet (.55 mm.)
TAP WATER	(1.5) Corrosion starting below water. (53) Surface deposit only, no pits.	(1) O.K. except rust on edges. (10) Slight corrosion below water.	(1.5) A few spots of corrosion. (16) Somewhat more corrosion below water. (53) Some corrosion and pitting below water; a few pits .035 mm. deep.
2-4-D ESTER	(1.5) Black greasy deposit below water. (from coated weld of asbestos sheet). (53) Greasy deposit, no corrosion, but about .001″ (.025 mm.) thinner below water.	(5) O.K., no change. (10) No change.	(1.5) O.K. (53) O.K., no change.
SODIUM T.C.A.	(1.5) Very badly corroded. (53) Heavy black layer .001″–.002″ thick just above water. .004″ (.101 mm.) thinner below water.	(5 hr.) Corrosion started. (5) Badly corroded. (10) All aluminum off below and above water, except for about 1″.	(1.5) Very badly coated with hard deposit. (8) Corroded worse than any sample. (33) Strip broke off just above water. (53) Disintegrated.
POLYBOR CHLORATE	(1.5) Slightly discoloured. (5) Badly corroded. (53) Deeply pitted above water; hard white deposit below water. Eaten through in two places.	(5) O.K. (10) Discoloured above water. Aluminum coating eaten away in patches.	(1.5) O.K. (16) O.K. (53) Some corrosion just above water-line.
ALDRIN	(1.5) Some corrosion on surface. (13) Corroded. (53) Surface pitted below water; pits .05–.1 mm. deep.	(5) Starting to discolour. (10) No apparent change.	(1.5) Large spots of white corrosion. (16) Considerable corrosion. (53) Quite badly corroded below water; a few pits .1–.3 mm. deep.
DIELDRIN	(1.5) Some corrosion. (53) No change, a film formed over zinc.	(5) Slightly discoloured. (10) Slightly discoloured below water.	(1.5) One lump of white corrosion. (16) Somewhat corroded. (53) Dark surface patches; a few pits .05–.18 mm. deep.
CHLORDANE	(1.5) Some corrosion. (53) Corroded at water-line; shallow surface corrosion below water.	(5) Slightly darkened. (10) Discoloured just above water-line; possible slight pitting.	(1.5) Slightly corroded. (13) Some corrosion. (53) Discoloured below water, pits above water .2–.25″ deep.

TABLE 1.—EFFECTS OF SPRAY MIXTURES ON SPRAY RIG MATERIALS—*Continued*

Spray Mixture	Aluminum Pipe and Brass Tube	Brass Sheet (.41 mm.)	Stainless Steel (.55 mm.)
TAP WATER	(1.5) Some white corrosion on pipe. (16) More corrosion. (53) Pitted slightly in spots above water.	(1.5) O.K. (53) Discoloured only, below water.	No change.
2-4-D ESTER	(1.5) O.K. (53) O.K. brass tube discoloured below water.	(1.5) O.K. (53) No apparent change.	No change.
SODIUM T.C.A.	(1.5) Very, very, badly corroded, pipe plugged with corrosion. (53) Very deeply pitted; pits .5–.8 mm. deep.	(1.5) Darkened. (53) Badly discoloured but no erosion noticed.	No change.
POLYBOR CHLORATE	(1.5) O.K. (53) Only darkened above water; O.K. below.	(1.5) Badly discoloured below. (53) Slightly darkened above water also but no change.	No change.
ALDRIN	(1.5) Large lumps of white deposit. (16) A good deal of corrosion. (53) A few pits on surface .15–.18 mm. deep.	(1.5) Discoloured at water line. (53) Discoloured only below water.	No change.
DIELDRIN	(1.5) One or two lumps of white corrosion. (53) Corroded patches on surface only.	(1.5) Slightly discoloured below water. (53) No change.	No change.
CHLORDANE	(1.5) Aluminum, slightly darkened, brass slightly corroded. (53) Pitted badly at water-line; pits .2–.4 mm. deep.	(1.5) Discoloured. (53) Discoloured only below water.	No change.

TABLE 1.—EFFECTS OF SPRAY MIXTURES ON SPRAY RIG MATERIALS—*Continued*

Spray Mixture	Copper Sheet (.45 mm.)	Asbestos bonded sheet steel (1) Bare seam (2) Coated seam	Steel Sheet with Kromer Finish "X"
TAP WATER	(1.5) O.K. (53) Slightly discoloured at water-line.	(1.5) Rust starting on bare weld. (53) Bare weld rusted; covered weld O.K.	No change.
2-4-D ESTER	(1.5) O.K. (53) Slightly green deposit, no corrosion.	(1.5) Bare weld slightly rusted. Coating on covered weld badly softened. (13) Coating on weld dissolving. (30) Asbestos coating very soft. (53) Asbestos very loose; coating off seam.	No change.
SODIUM T.C.A.	(1.5) Quite badly discoloured. (13) Corroded. (53) Badly darkened but no erosion.	(1.5) Both O.K. (53) No change; bare seam slightly rusted.	(53) No change; rusted slightly on edge where coating thin.
POLYBOR CHLORATE	(1.5) Slightly discoloured. (53) Slightly discoloured above and below water.	No change.	No change.
ALDRIN	(1.5) O.K. (53) Discoloured only below water.	(1.5) Asbestos coating loosening at edge. (53) Coating somewhat softened below water. Coated seam softened. Bare seam somewhat rusted.	No change.
DIELDRIN	No change.	(1.5) Asbestos coating loosened at edge. Seam coating slightly soft; not as bad as in Aldrin. (53) Coated seam O.K.; slight rust on bare seam; coating slightly loosened.	No change.
CHLORDANE	(1.5) Discoloured below water. (53) No change.	O.K.; no change.	No change; slight rust on edges.

TABLE 1.—EFFECTS OF SPRAY MIXTURES ON SPRAY RIG MATERIALS—*Continued*

Spray Mixture	Bonderized Steel Sheet Bonderized No. 160 Coated with Permolite No. 40 Prime	Bonderized Steel Sheet Bonderite No. 160 Permolite coating No. 40 + Permolite No. 11	Bonderized Steel Sheet Bonderite No. 1000 Permolite No. 40 Prime Coating
TAP WATER	No change.	(53) Checked.	No change.
2-4-D ESTER	(1.5) Very badly loosened all over. (3) Completely loose below water. (6) Some corrosion beginning. (53) Paint gone below water.	(1.5) Badly loosened at edge. (3) Completely loose below water. (6) Corrosion beginning. (53) Paint gone below water.	(1.5) Very badly loosened all over. (3) Completely loose below water. (6) Some corrosion beginning. (53) Paint gone below water.
SODIUM T.C.A.	(1.5) Slightly loosened below water. (5) O.K. (16) Beginning to flake off. (53) Loosened above and below water; pits .1–.25 mm. deep below water.	(1.5) O.K. (16) O.K. (53) Checked below water. Partly loosened above water.	(1.5) O.K. (6) Loosened above and below water. (53) Rust beginning under coating; pits .05 mm. deep.
POLYBOR CHLORATE	No change.	No change.	No change.
ALDRIN	(1.5) Beginning to loosen. (16) Slightly loosened. (53) Loose, but still adhering.	(1.5) O.K. (16) O.K. (53) Checked only, scraped off with finger-nail with difficulty.	(1.5) Beginning to loosen. (13) Slight loosening. (53) Paint loosened somewhat but still adhering.
DIELDRIN	(1.5) Very loose. (3) Paint off. (53) All paint off.	(1.5) O.K. (5) Loosened slightly. (53) Still on, but badly checked and loosened.	(1.5) Starting to loosen at edges. (16) Loosened somewhat. (53) Loose at edges only.
CHLORDANE	(1.5) O.K. (16) Loosening. (53) Badly loosened.	(1.5) O.K. (16) Firm. (53) Checked and loose at edges only.	(1.5) O.K. (3) O.K. (53) Loosened at edges and at water-line.

TABLE 1.—EFFECTS OF SPRAY MIXTURES ON SPRAY RIG MATERIALS—*Continued*

Spray Mixture	Bonderized Steel Sheet Bonderite 1000 Permolite No. 40 and Permolite No. 11	General Purpose Paint Coating Dorman Co., Cambridge	Acid Resistant Paint Dorman Co., Cambridge
TAP WATER	(1.5) O.K. (53) Checked.	No change.	No change.
2-4-D ESTER	(1.5) Badly loosened at edge. (3) Completely loose below water. (6) Corrosion beginning. (53) Both paints gone below water.	(1.5) Discoloured and loosened all over. (3) Badly loosened and partly off; corrosion beginning. (53) All off below water. O.K. above.	(1.5) Badly loosened all over. (3) Badly loosened and off. (6) Corrosion beginning. (53) All off below water; O.K. above.
SODIUM T.C.A.	(1.5) O.K. (6) O.K. (53) O.K. below water, and partly loosened above water.	(1.5) O.K. (5) Blistering slightly. (53) Blistered, especially above water but not loosened much.	(1.5) Paint slightly lifted at bottom edge. (16) Sticky above water. (53) Loosened below water.
POLYBOR CHLORATE	No change.	No change.	No change.
ALDRIN	(1.5) O.K. (30) O.K. (53) Holding better than No. 160; could not scrape off with finger-nail.	No change.	No change.
DIELDRIN	(1.5) Slightly loose at edge. (13) Loose at edges only. (53) Checked; slightly loose at edges; scraped off with finger-nail with difficulty.	(1.5) Soft and pitted. (3) Quite soft. (13) Slightly loosened. (53) Fairly tight but blistered.	(1.5) Loosened below water. (3) Quite soft. (13) Slightly loosened. (53) Slightly loosened at edges and looser when wet.
CHLORDANE	(1.5) O.K. (3) O.K. (53) Checked and loose at edges only.	No change.	(1.5) O.K. (3) O.K. (53) Paint blistered and somewhat loosened.

TABLE 1.—EFFECTS OF SPRAY MIXTURES ON SPRAY RIG MATERIALS—*Concluded*

Spray Mixture	1/2" Rubber Water Hose	3/4" Rubber Sprayer Hose	"Uscolite" Pipe and Brass Fitting
TAP WATER	No test.	No test.	No test.
2-4-D ESTER	(1.5) O.K. (3) Badly swelled. (53) Very badly swelled and softened especially at ends.	(1.5) Softened on outside. (3) Badly swelled. (53) Very badly swelled and softened especially at ends.	(1.5) Beginning to soften at edges. (3) Quite soft on surface. (13) Badly softened. (53) Badly swelled and softened; nozzle not loosened much.
SODIUM T.C.A.	No change.	No change.	No test.
POLYBOR CHLORATE	No change.	No change.	No test.
ALDRIN	No change.	No change.	No change; brass nozzle tight.
DIELDRIN	No change.	No change.	(1.5) Very slight softening below water. (53) Little change. Slightly softer on edges below water.
CHLORDANE	No change.	No change.	No te t.

TABLE 1.—EFFECTS OF SPRAY MIXTURES ON SPRAY RIG MATERIALS—*Continued*

Spray Mixtures	*Baked Phenolic Coating as used on Chlordane cans	*Aluminum Pipe and Cadmium Plated Brass Tube	*1/2" Plastic Hose as Used on Milking Machines (Tested at 250 lb.)	*1/2" Plastic Hose as Used on Buffalo Turbine (Tested to 300 lb.—test two weeks only)
TAP WATER	Coating loosened below water and iron rusted	Cadmium almost gone.	No change.	No change.
2-4-D SODIUM SALT 1#/acre rate	Coating loosened above water.	Cadmium all gone and brass badly discoloured.	No change.	No change.
2-4-D AMINE 1#/acre rate	No change.	Cadmium slowly disappearing below water.	Turned greenish shade.	Turned greenish shade.
2-4-D ESTER 1#/acre rate	No change.	Cadmium all gone below water after 3 days.	Burst at 220 lb.	Softened and bulged on test.
CHLORDANE 1 lb./acre rate	No change.	Cadmium all gone and severe corrosion on brass at joint.	No change.	No change.
TOXAPHENE 1–1/2 lb./acre rate	No change.	No test.	No change.	No change.
Mixture of 2-4-2 ESTER and CHLORDANE each at 1 lb./acre	Coating somewhat rough in spots.	Cadmium *all* gone. *Worst* corrosion on brass and at joint.	Somewhat softer; bulged on test.	Somewhat softer; bulged on test.

* Results from three-week test in 1949.

TABLE 2.—OBSERVATIONS AFTER 21 MONTHS—3 MATERIALS WITH 6 SPRAY SOLUTIONS

Spray Mixture	Tinned Iron (Oil Can) (.011″ thick, or .30 mm.)	Tin Can (Food Container) (.013″ thick, or .35 mm.)	Heavy Galvanized Iron Can (.041″ thick, or 1.04 mm.)
2-4-D SODIUM SALT 1 lb. acid to 4 gal. water	Tin plate eaten off. .08 mm. thinner.	Rust spots above water. A few below water also.	Blackened .039″ below water. .041″ above water.
2-4-D AMINE 1 lb. acid to 4 gal. water	No change.	No change.	No change.
2-4-D ESTER 1 lb. acid to 4 gal. water	No change.	Slightly more rusty below water.	Blackened. .039″ thick below water.
CHLORDANE 1 lb. acid in 4 gal. water	Deeply pitted quite evenly over surface. (pits av. 0.05 mm. deep).	Very rusty and pitted over whole surface. Some pits through metal.	Badly corroded. Coating of corrosion on surface. .039″ thick below water.
TOXAPHENE 1-1/2 lb. acid in 4 gal. water	No apparent change.	Rust spots evenly distributed. Some pits .05–.2 mm. deep.	Badly blackened below water (about .03 mm. less below water).
ESTER AND CHLORDANE Mixture each at 1 lb. acid in 4 gal. water	Several pits through metal. Tin eaten away mainly at surface of liquid.	Quite rusty and pitted; pits .1–.3 mm. deep.	Badly corroded but not eaten away.

Iron, zinc and aluminum, whether used as metal coatings or pure metals, seem to be more subject to attacks from the chemicals than are other metals.

As far as paint coatings are concerned it would appear that brush coatings generally are considerably less resistant to chemical action than baked coatings.

Bonderizing, using iron phosphate coating, would seem to be slightly superior to Bonderizing where zinc and iron phosphate coating is used.

As to length of test, one month is ample time to show up any effects that may appear.

Recommendations

In the light of the foregoing results the authors consider that the following recommendations to both operators and manufacturers are justified:

1. All spray machines using these chemicals should be thoroughly flushed out at the end of each season, or when the machine is to be idle for several days. Unused solution should not be allowed to stand in the machine for any length of time. This is more important where metals such as galvanized iron and aluminum are used.
2. Where the action is severe such as between aluminum and T.C.A., the machine should be flushed thoroughly each night.
3. At the end of the season, particular care should be taken in the flushing operation and to see that all parts are so arranged that they will drain as completely as possible, to allow the metal to dry.
4. Iron should not be used in construction unless covered with a metallic or paint coating.
5. If paint coatings are used they should be of the acid-resistant baked type, particularly on those parts in contact with the spray solution.

From the results obtained it may be concluded that the life of a field sprayer will depend largely upon proper operation and care when in use, and upon proper care between seasons. The average machine should last for many years if the above suggestions are followed and if the solutions used are no more corrosive than those tested.

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SAFFLOWER—CANADIAN EXPERIMENTS[1]

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Since ancient times safflower (*Carthamus tinctorius* L.) has been widely cultivated in the Middle East and Northern Africa both as an oil-seed and for the reddish dye in the flowers (carthamin). The importance of this plant as a source for dye has declined greatly since the introduction of synthetic dyestuffs. It is an important oil-seed crop in the Bombay Presidency and even in the driest areas of Southern India where the oil is used for edible purposes and as a soap oil. China and Turkistan grow this crop as do the Ukraine and other areas of the Soviet Union.

Safflower was introduced into the United States in 1899 (7). However, no serious effort was made to grow it until 1925 when seed of Russian origin was distributed to several experimental stations. The first tests were not encouraging and interest in the crop was kept alive chiefly by a small group of farmers in Montana who introduced many strains. In 1942 the Chemurgy Project of the University of Nebraska began a breeding project on this crop. Since that time sufficient progress has been made towards the production of improved lines that safflower has now become a commercial crop in Nebraska and several of the adjoining states.

Tests of safflower were commenced by the Cereal Division of the Central Experimental Farm at Ottawa in 1936. A number of types were procured from A. H. Rehbein of Lambert, Montana. Later, introductions of European and Asiatic origin were obtained and, more recently, in co-operation with C. Claassen of the Chemurgy Project, many of the improved strains from Nebraska have been grown in Canada.

CHARACTERISTICS OF THE PLANT

Safflower is an erect, glabrous, thistle-like herbaceous annual of the Composite family, with white to reddish orange flowers (Figure 1). The stem is 1 to 3 feet high, considerably branched at the top, approximately $\frac{1}{4}$ inch in diameter. It does not crinkle or lodge. The leaves are sessile, oblong, with serrate edges to nearly entire, strongly or scarcely spiny. All branches are terminated by globular flowering heads $\frac{1}{2}$ to $1\frac{1}{2}$ inches in diameter with a series of heavy involucral bracts. The head is composed of 20 to 80 florets, each of which is capable of producing one seed. Blossoming begins on the main branch, followed by the later secondary branches. According to Claassen (4), the flowering period extends from 10 to 40 days depending upon temperature, rate of planting, and moisture supply. The florets at the margin open first and flowering proceeds centripetally over a period of 3 to 5 days. At Ottawa blossoming occurs around the end of July. During this time bees have been observed to be very active. Studies by Claassen (4) indicate that although there was extreme variability most plants were outcrossed from 5 to 40 per cent. Insects accounted for most of the cross pollination. Howard *et al*, (6) report an average of 16.5 per cent cross pollination and stated that bees were not necessary for

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FIGURE 1. Typical flowering safflower plant produced in a 12-inch row plot; *left insert*, leaf; *right insert*, flowering heads, one of which is sectioned to show position of seed.

pollination, provided the covering of the plant was sufficiently open so that air movement and humidity were not interfered with. Similar results were found at Ottawa although the part of the plant covered with paper bags produced fewer seeds per head than the non-covered portion subject to open pollination. Lines tested at Ottawa have generally shown a considerable variation in plant characters.

The seed is smooth, obovoid, 4-angled, white to cream coloured, resembling sunflower seed in appearance and barley grain in size. The types under test have varied from 35 to over 50 grams per thousand kernels, and the test weight of good quality seed varies from 37 to 48 pounds per bushel. Safflowers mature in September and harvesting can be delayed if desired as the seed resists shattering.

Safflower is planted about the same time as small grains. Emergence of the crop above ground varies from 5 to 20 days after seeding, depending upon soil temperatures. In Nebraska, safflower is considered more resistant to spring frosts than flax, seedlings withstanding temperatures down to 10° to 15° F. (5). Growth is slow in the early stages and for this reason clean stands of safflower may be difficult to obtain. Once in flower it is damaged by any temperatures below freezing.

COMMERCIAL USES OF SAFFLOWER

Safflower is grown for its seed. The most valuable product is the oil obtained. The seeds possess a rather heavy hull which varies from 35 to 50 per cent. The oil content is variable and lines produced by the Nebraska Experiment Station have yielded as high as 38 per cent.

The oil is characterized by high linoleic acid content (approximately 75 per cent) and very low linolenic acid content (0 to trace). For this reason Carrick and Nielson (1) suggest that it should find application in any formulation where sunflower and soybean oil are utilized. They studied its possibilities in protective coatings and concluded that it would be a satisfactory vehicle in outside paints, inside enamels, as a source of heat-treated oils of high linoleic acid content, and in the preparation of alkyd resins. The iodine value of the oil ranges from 140 to 150, as compared with soya bean oil of 130 to 140 and linseed oil which in Canada ranges from 180 to 200. Remington (10) points out that its great advantage is its low acid value.

Winter (12), summarizing the experiments with safflower oil in Australia, states: "Under practical conditions the drying power of safflower oil equals that of linseed oil". They found that after 3 years of outdoor exposure tests, paints based on safflower oil have performed at least as well as similar paints from linseed oil. Commercial production by solvent extraction presented no difficulty and gave an oil of very good colour and free from impurities.

Packer and Christensen (8) report results equally as favourable. Metallic driers effectively accelerated the drying rates of both linseed and safflower oils, but had a larger influence on the latter. They attributed the low degree of after-yellowing of safflower oil paints and enamels, in comparison with those made from linseed oil, to the absence of linolenic glycerides. Apparently the colour bodies present in safflower oil are primarily

carotenoid which decompose under cooking temperatures and this brings about a very high degree of heat bleachability. House paints made with safflower oil were shown to have lower viscosity, better flow, and easier grinding characteristics as compared with linseed. Drying times of the two were identical although the film hardness of safflower was slightly superior after 3 days.

The seed meal or residue remaining after the extraction of the oil may be used for livestock feeds. The protein content varies with the amount of seed hull removed during the oil extraction. Limited research has been conducted on uses other than as a livestock feed. Knowles and Davis (7) state that experiments in the Poultry Division of the University of California have shown this meal to be deficient in the amino acids, methionine, and lysine. Due to this deficiency it should be supplemented with other protein feeds containing these amino acids. Compared with soybean meal, a meal containing 42 per cent crude protein gave slightly higher gains in feeding tests for wintering calves, and for fattening yearling steers or lambs (5).

EXPERIMENTAL RESULTS

Many lines of safflower have been introduced since experimental investigations were commenced on this crop. The original lines received in 1936 from A. H. Rehbein of Lambert, Montana, were designated as Types 1, 6, 14 and 25. The following year C.D. 2650 and C.D. 2651 were introduced from the United Provinces of India as types 7 and 56 respectively. In 1940, C.D. 3228, 3229 and 3238, obtained from D. Demetrovits, Brooks, Alberta, were said to have originated in Hungary. Pusa No. 2, Pusa No. 7 and Karrar were forwarded by F. Rabak, of the U.S. Department of Agriculture. Other varieties were kindly supplied by C. Claassen, of the University of Nebraska Experimental Station. More recently these introductions have included many selections which carry the prefix "N-" and are the result of breeding work conducted at that Station.

Tests have usually been grown in randomized, quadruplicate plots of three rows each, $18\frac{1}{2}$ feet long. The rows were spaced 1 foot apart in most instances, except at the Lethbridge Station where some have been seeded in rows 22 inches apart. Seedings were made about as early as the land could be prepared. In some cases harvesting has been delayed beyond maturity to check the possibility of shattering.

In 1941 an environmental study was arranged to determine in which areas the crop might show possibilities. Table 1 gives the results of a test of 5 lines in each of 6 provinces. The trials at Fredericton, New Brunswick, were not satisfactory as the season was wet and the crop did not mature properly. The yields were low and the seed was extremely shrivelled and undeveloped. The low oil content would also indicate poor quality. The crop from Agassiz, B.C., was much better but still did not compare with that from the Prairie Provinces. These samples, like those from Fredericton, were also badly weathered. It will be noted that environment in this season appeared to have a greater influence on oil content than on iodine number. In several instances it was observed that samples with plump kernels contained shrivelled contents or were completely empty. The proportion of these in a sample will affect the analyses for quality and is usually reflected in a low weight per bushel. F. Rabak (9) has made the

TABLE 1.—SAFFLOWER TESTS AT DIFFERENT STATIONS 1941

Station	Yield per Acre in pounds					Days to Mature				
	Type 1	Type 6	C.D. 2650	C.D. 3229	C.D. 3230	Type 1	Type 6	C.D. 2650	C.D. 3229	C.D. 3230
Agassiz	1014	750	640	476	487	128	130	128	132	132
Lethbridge	2773	3330	2885	1704	1946	—	—	—	—	—
Indian Head	1988	1896	1895	1124	988	122	122	122	127	127
Morden	1659	1990	1838	2561	2907	104	104	104	117	117
Ottawa	882	859	886	911	962	128	128	128	134	134
Fredericton	248	299	286	41	40	122	122	122	140	140
Mean	1427	1521	1405	1136	1222	120.8	121.8	120.8	130.0	130.0
	Oil Content in Per cent					Iodine Number				
Agassiz	21.3	19.3	21.4	10.8	10.6	146	144	144	139	139
Lethbridge	23.4	22.9	23.8	9.9	12.6	149	149	149	146	147
Indian Head	19.5	19.8	16.8	7.2	5.3	147	148	148	142	138
Morden	26.5	25.4	26.5	21.1	21.4	146	146	147	147	147
Ottawa	23.3	22.7	23.4	17.1	16.9	146	144	143	145	146
Fredericton	6.9	7.4	7.0	1.7	3.2	145	142	142	136	138
Mean	20.1	19.6	19.8	11.3	11.7	146.5	145.5	145.8	145.5	142.5

observation that low oil content may be due to unfavourable seasonal conditions at the time of seed setting in the plants. Unless good pollination is obtained many unfilled or light seeds result. From observations made in Texas (10) it has been concluded that the most successful cultivation of the crop may be limited to areas of relatively light rainfall and that it may not do well in sections of the country where the rainfall is more than 25 inches. Claassen (5) stated that the crop is adapted to areas where dry atmospheric conditions prevail from the time of flower bud formation until maturity. Low relative humidity is essential for good seed set and high oil content.

It will be noted in Table 1 that the varieties appear to fall into two groups. C.D. 3229 and C.D. 3230, originating in Hungary, differed from the other selections in many characteristics. Compared with the material received from Mr. Rehbein, this group is characterized by a more vigorous growth, maturing about 6 inches taller and practically spineless. The data indicate that these two varieties are late maturing with low oil content and iodine number. In addition they were low in yield at all stations except Morden, Manitoba.

VARIETY TESTS IN ONTARIO

Experimental tests on safflower at the Cereal Division, Ottawa, have been continued since the first lines were introduced in 1936. The line designated as Type 25 was received by Mr. Rehbein of Montana and has been used as a check in these experiments. The lines tested over a longer period than more recent ones have behaved similarly as regards both yield and oil content. In view of Dr. Claassen's report (4) of a considerable amount of cross fertilization, there is a high probability that these lines were intercrossed a great deal since seed from adjoining plots was used for the following year's crop. It is not known how long some of them may have been grown together before they were received here. Lines introduced more recently showed much greater uniformity. It was disappointing that the new introductions from Nebraska (N. 805 and N. 852) did not yield a better crop of seed. From Table 2 it will be noted that selections

TABLE 2.—SUMMARY OF ROD ROW TESTS OF SAFFLOWER AT OTTAWA, ONTARIO

	Yield per Acre		Mean of Quality Tests		
	No. years tested	Av. in lb.	No. years tested	Oil content %	Iodine number
Type 25	10	1044	9	22.1	146
Type 1	8	1403	6	21.1	146
Type 6	6	1416	5	21.3	145
Type 14	6	1397	5	22.0	146
C.D. 2650	6	1282	5	22.4	145
C.D. 2651	6	1313	5	22.0	145
Pusa 2	5	1097	5	22.7	145
Pusa 7	5	1311	5	23.3	147
Pusa 14	5	1287	5	24.6	143
Ahmednagar	2	1484	3	25.6	143
Sholapur	2	1452	3	23.5	149
Kardai	2	1086	3	26.3	141
Neb. 852	3	680	3	22.1	146
Neb. 805	3	823	3	25.7	145

designated Pusa 2, 7 and 14, particularly the last, have a slightly higher oil content than the types received earlier. The Nebraska selections were higher, N. 805 producing over 31 per cent of oil in 1949.

TESTS IN THE PRAIRIE PROVINCES

In 1942 in the Morden and Indian Head tests, Types 1 and 6 and C.D. 2650 were grown, and in 1943 and 1944 two strains of Pusa and Karrar were received from F. Rabak. In each season successful yields were obtained at Morden as shown in Table 3. Four seasons' data at Indian Head are summarized in Table 4. It will be noted that in each of the years 1942 to 1944 the tests at Indian Head were damaged by frosts in

TABLE 3.—DATA ON SAFFLOWER TESTS AT MORDEN, MANITOBA

Average for Years 1941–1942

Variety	Days to maturity	Height	Test weight	Oil content	Iodine number	Yield per acre
		in.	lb.	%		lb.
Type 1	110.5	29.2	46.5	25.2	148.4	1684.5
Type 6	118.2	29.0	45.5	24.3	148.0	1913.5
C.D. 2650	118.2	29.5	45.5	25.1	148.8	1934.0
Variety Test in 1943						
Pusa 7	130.0	30.0	—	—	—	1952.2
Pusa 7	130.0	26.0	—	—	—	1899.7
Karrar	130.0	28.0	—	—	—	1484.5

TABLE 4.—DATA ON SAFFLOWER TESTS AT INDIAN HEAD, SASK.

Average for Years 1941–1942

Variety	Height	Test weight	Weight per 100 K.	Oil content*	Iodine number*	Yield per acre
	in.	lb.	gm.	%		lb.
Type 1	28.2	33.5	34.8	19.5	146.9	1079
Type 6	28.3	32.5	35.0	19.8	148.2	1052
C.D. 2650	27.2	33.5	36.0	16.8	147.8	1037

* 1941 crop only—1942 crop damaged by frosts Sept. 17, harvested Sept. 29.

Average for Years 1943–1944**

Variety	Height	Test weight	Weight per 1000 K.	Oil content*	Iodine number*	Yield per acre
	in.	lb.	gm.	%		lb.
Pusa 2	20.3	42.0	40.2	26	148.4	1304
Pusa 7	21.6	40.3	43.0	20	146.3	1147
Karrar	21.8	36.0	48.4	21.5	146.8	1082

**1943 only crop frosted Sept. 16, harvested Sept. 29—germination 60%.
1944 crop harvested Sept. 23 before fully mature; quality data not available.

early September before they were fully mature. This consequently lowered the test weight of the seed and reduced the quality. However, in a test plot at Brandon, Manitoba, safflower was not damged by frosts that injured corn.

More successful trials with safflower were obtained at the Lethbridge Experimental Station on irrigated land. Data in Table 1 indicate that the early varieties at this Station exceeded all others in yield per acre. Tests have been continued here and the data are given in Table 5. On the average of 5 years, Type 1 yielded almost 2500 pounds of seed per acre. Slight differences in maturity were observed among the varieties within a season, although the differences between seasons were quite marked ranging from 127 days in 1942 to 150 days in 1943. Pusa No. 2 was the earliest in maturity of the group and the shortest in height. Usually the test was subjected to only one irrigation in late June or early July.

TABLE 5.—VARIETY TEST OF SAFFLOWER AT THE DOMINION EXPERIMENTAL STATION LETHBRIDGE, ALBERTA, 1942–45 AND 1948

Variety	Yield per acre	Oil content*	Iodine number*	Wt. per bu.**	Wt. per 1000 K**
	lb.	%	Wijs.	lb.	gm.
Type 1	2461.4	21.2	148.8	45.5	39.9
Type 6	2241.9	20.2	148.6	46.5	41.6
C.D. 2650	2089.1	22.9	149.7	46.2	39.5
Mulligans No. 2	2360.7	21.5	147.8	48.2	42.0
Pusa No. 2	1684.9	27.2	148.3	43.5	48.4
Pusa No. 7	1640.4	20.6	147.2	44.0	48.8

* Average 1942–43.
** Average 1944–1945.

TABLE 6.—VARIETY TEST OF SAFFLOWERS AT DOMINION EXPERIMENTAL STATION, LETHBRIDGE, 1950

Variety	Irrigated Land				Dry Land			
	Height	Av. acre	Oil content	Iodine number	Height	Av. acre yield	Oil content	Iodine number
	in.	lb.	%		in.	lb.	%	
Indian	29	767	11.6	144	24	884	24.6	147
N. 3	33	764	16.8	147	28	1210	24.8	149
N. 4	—	740	10.9	144	—	909	24.6	149
N. 6	24	265	17.5	144	26	923	26.5	149
N. 8	32	495	27.9	148	25	904	29.2	148
N. 9	—	—	—	—	23	976	35.1	143
N. 10	29	467	18.7	147	25	1366	33.7	147
N. 472	—	318	7.6	143	—	782	24.0	148
N. 805	—	619	8.0	143	—	1237	28.3	148
N. 852	21	149	19.4	144	27	1282	31.4	146
N. 688-7-2	27	552	13.5	145	23	1085	31.7	149
N. 2377	32	740	13.8	146	29	974	28.0	148
Dakota flax	—	1107	38.4	188	24	547	39.5	192
Mean for safflower		532				1044		
Sig. Diff.		167						

During this period tests were also conducted on dry land at the Lethbridge Experimental Station. Yield and size of seed, as indicated by weight per 1000 kernels, were lower than the results received from the irrigation experiment.

A co-operative regional nursery, originating with the Chemurgy Department of the Nebraska Experimental Station, was grown on both dry and irrigated land at Lethbridge, Alberta, in 1950. Dakota flax was grown for comparison. Root rot was severe in the plots on irrigated soil. The data given in Table 6 show very favourable yields in the dry land test with an oil content appreciably higher than in material previously tested.

PRODUCTION METHODS

Little is known regarding production methods under conditions in Canada. Treatment of the seed with 2 ounces of a mercuric dust fungicide per bushel is recommended for disease control. Safflower competes better with weeds than flax although not as well as do wheat or other cereals. The seedbed, therefore, should be well prepared to eliminate as many weeds as possible before planting. Safflower should be planted early in the northern climate, in order that it may reach proper maturity. In the seedling stage safflower appears to have as much cold tolerance as the cereals and may be seeded as early as the first wheat. Experiments conducted at the Lethbridge Experimental Station have illustrated that yields are reduced proportionally with each extended date of seeding and very late seeding resulted in serious yield reductions. The data are given in Table 7. The first seeding in 1944 was April 25, while that in 1945 was May 11, followed by seedings every week to 10 days. Since this crop requires a full growing season to mature, it should be seeded as early as wheat.

Safflower may be seeded solid or in cultivated rows but it is doubtful if the extra cost of cultivation would warrant the yields received. In the Great Plains States a light cultivation, just before the seed leaves appear above the surface of the ground, has been found to be quite successful in the control of weeds. A light harrowing crosswise or diagonal to the rows destroys small weeds. A similar cultivation is often repeated when the stems are 3 to 6 inches high. Harvesting with the combine has been successful and while the plant is resistant to shattering, some losses have occurred where the crop was late. The speed of the cylinder should be reduced and

TABLE 7.—DATE OF SEEDING OF SAFFLOWER AT DOMINION EXPERIMENTAL STATION LETHBRIDGE, ALBERTA

Date of Seeding	Irrigated Land Av. 1944–45				Dry land 1945			
	Length of straw	Test weight	Wt. per 1000 K.	Yield per acre	Length of straw	Test weight	Wt. per 1000 K.	Yield per acre
	in.	lb.	gm.	lb.	in.	lb.	gm.	lb.
First date	27.2	47.5	42.2	3234	24.5	48.0	37.2	1674
Second date	26.7	45.5	42.0	3487	22.8	44.5	39.6	1558
Third date	23.4	43.0	39.5	2232	19.0	38.5	34.4	901
Fourth date	24.0	34.5	34.0	1534	Discarded—too poor stand			

some other adjustments may be necessary. Some empty seeds will blow over with the straw. Cracked seeds are considered objectionable and not over 5 per cent damage is allowed in No. 1 seed as a standard of the Minneapolis Grain Inspection Department.

DISEASES

The disease of safflower most commonly found in Canada is rust (*Puccinia carthami*). First observed here in 1942, it was estimated that 20 per cent of the plants at Morden were infected. A moderate infection occurred again in 1943 and light-to-moderate infections were found at Lethbridge in 1944, 1945, 1947 and 1949. In 1950 slight-to-moderate infections were noted on most lines except N. 6 and N. 852. Infection was also present at Saskatoon in 1942 and 1944 (3).

A root rot caused by a species of Fusarium infected the plots at Lethbridge in 1945. It was estimated that approximately 3 per cent of the plants were affected. This disease is stated to be more prevalent on irrigated than on dry land (3). In 1950, on irrigated plots at Lethbridge, N. 852 was damaged to the extent of 80 per cent and N. 9 was discarded because of this disease. Some varieties may have to be discontinued on irrigated land because of their susceptibility to root rot.

Other diseases have been noted. A wilt was observed at Lethbridge in 1949. Several of the strains from Nebraska were found to be highly resistant. Leaf spots have been reported at Ottawa and Winnipeg caused by *Macrosporium carthami*. The diseases of safflower were reviewed by Conners (2). There is evidence of experimental material resistant to rust, bud rot, leaf spot, and root rot being available (5).

Insect damage appears to be rather light although it is reported (5) that the crop is subject to grasshopper damage. Pheasants and rodents are fond of the seed.

POSSIBILITIES FOR FURTHER PRODUCTION

It should be pointed out that selection or breeding work with safflower has been limited in Canada. The lines under investigation are those introduced from the United States or elsewhere. Experiments have indicated that on the Prairies they are frequently touched by frost and may be late even for southern Alberta, especially when grown on irrigated land. These varieties have been found susceptible to rust, root rot, leaf spots and other diseases, particularly on irrigated land. It would appear, therefore, that there is a need for suitably adapted and disease-resistant varieties.

The first strains of safflower tested were so low in oil content as to be considered unprofitable for commercial production. However, the higher oil producing strains more recently developed place safflower next to flax among the oil crops which can be grown in Canada. While the oil can be used for edible purposes, the present commercial use in the United States is in the paint and varnish industry. Safflower can, therefore, best be compared with flax. Flax contains an average of 40 to 42 per cent of oil, a 12-bushel crop producing about 225 pounds per acre. With safflower containing 25 to 30 per cent of oil, an equivalent amount of oil would be produced by an 800- to 900-pound crop. In southern Alberta safflower

appears to fight weeds better than flax, to be as easily handled as flax, and to produce yields comparable to flax. It remains to be seen whether the farmer can grow the crop as economically as flax, wheat, and other cash crops in these areas.

With experiments on a larger scale much information regarding the methods of culture adaptable to the area in which the crop may be grown is being obtained. Considerable work is needed in connection with the recommendation of economical machinery and its proper adjustments for this crop.

In the meantime, a program of breeding and selection towards the production of varieties with greater yielding ability and adaptability should result in safflower having a place among the oil-bearing crops in Canada.

SUMMARY

The characteristics of the safflower plant are described and illustrated. The most valuable product is the oil in the seed. Experimental studies indicate its greatest value as a drying oil.

Safflower has been tested by the Cereal Division since 1936. Twenty-six lines of different origin have been grown. Tests in six provinces have indicated that greater yields were obtained in southern Alberta. At the Experimental Station at Lethbridge much greater yields have been obtained on irrigated land than on dry land, although the incidence of disease was greater and maturity was retarded by a week or more. Early seedings gave greater returns.

In southern Alberta safflower appears to be able to compete with weeds, to be easily handled and give favourable yields. Considerable work on a larger scale would appear necessary to indicate whether safflower can be grown as economically as other cash crops.

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TESTS OF VARIOUS INSECTICIDES AGAINST THE CABBAGE MAGGOT ATTACKING RADISH, 1948-1950[1]

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INTRODUCTION

Mercury bichloride and calomel for many years have been the chemicals most commonly recommended for the control of root maggots attacking cabbage, cauliflower, and radish in Canada. They usually give adequate protection of cabbage and cauliflower, but unsatisfactory, or variable, protection of radish. Recently certain of the newer insecticides, notably the chlorinated hydrocarbons, have been shown to be highly toxic to root maggots. Stitt (4) found that chlordane, aldrin, and dieldrin gave good control of root maggots attacking radish. Crowel *et al.* (1) showed that BHC gave excellent protection of radish, kohlrabi, broccoli, mustard, and rutabaga. Eide and Stitt (3) demonstrated the toxicities of BHC, chlordane, aldrin, dieldrin, and lindane to root maggots attacking broccoli, cauliflower, and seedbed cabbage. The present paper is a report on experiments at Ottawa, 1948–50, on the toxicities of several insecticides to the cabbage maggot, *Hylemya brassicae* (Bouché), radish being used as a test plant.

MATERIALS AND METHODS

The experimental plots, consisting of single 10-foot rows, were arranged in 4 randomized blocks in 1948 and 1949, and in 6 randomized blocks in 1950. The radish, variety Saxa Forcing, was seeded by hand on the following dates: May 12, 1948; May 20, 1949; May 12, 1950. These dates were chosen so that the insecticides might be tested under conditions of maximum infestation each year; Table 1 shows that *Hylemya* spp., principally the cabbage maggot, begin to lay their eggs on cabbage at Ottawa about May 15 in an average year, and that their egg-laying reaches its peak toward the end of May. However, in 1949 seeding was unavoidably delayed until May 20, and the peak of egg-laying occurred only 4 days later.

Table 1.—Records of *Hylemya* eggs on 25 early cabbage plants in the same test field, Ottawa, May 5–June 15, 1946–1951

Year	*Hylemya* eggs		Date first eggs found	Peak of egg-laying
	Total number counted in 42 days	Average number per plant per day		
1946	3,205	3.1	May 10	May 26
1947	1,621	1.5	May 20	June 6
1948	425	.4	May 12	May 29
1949	2,315	2.2	May 11	May 24
1950	2,764	2.6	May 22	May 29
1951	12,343	11.8	May 14	May 29
Average	3,779	3.6	May 15	May 29

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Tables 2, 3, and 4 show the insecticides and the concentrations at which they were tested. The dusts were applied with a knapsack, bellows-type duster in 1948; in 1949 and 1950 they were sifted upon the plants through a double layer of cheesecloth. The average rate of application was 13 ounces per 100 feet of row, 350 pounds per acre. The solutions, emulsions, and suspensions were applied as drenches poured along the rows at 1 gallon to 40 row-feet, 1,085 gallons per acre. Two applications of the materials were made at 10-day intervals, beginning a day or two after most of the plants had appeared above the soil; the first application was made on May 20 in 1948, on June 3 in 1949, and on May 26 in 1950. The radishes were harvested, washed, and inspected 10 days after the second application, the criterion of insecticide efficiency being whether the roots were injured by maggots or not. As is usual in thickly seeded plantings of radish, not all the plants had well-developed roots at harvest; about 60 per cent formed bulbous roots, those of the others being thread-like or spindly. Maggot injury records were taken on both types of roots, but the data for the spindly roots have been omitted because the results were similar.

The phytotoxicities of the chemicals were judged by foliage injury records taken 7 days after the second application and by yield records at harvest. The foliage injury records were based on the degree of injury to each plot as a whole; the yield records were similarly based on the weights of the roots.

RESULTS

There was a significant infestation of root maggots in the experimental field each season. The infestation was moderate in 1948 and severe in 1949 and 1950. Collections in 1948 and 1950 showed that the cabbage maggot, *H. brassicae*, was responsible for most of the damage to the radish roots; of 98 and 144 maggots collected, 92 and 84 per cent respectively were of *H. brassicae*. The remainder were of *H. cilicrura* (Rond.) and *H. trichodactyla* (Rond.).

Data on the effectiveness of the materials are summarized in Tables 2–4. In 1948, dusts of BHC, chlordane, calomel, and parathion gave moderate control of the maggots. Calomel suspension gave slight protection, but DDT dust and mercury bichloride solution were ineffective.

TABLE 2.—CONTROL OF THE CABBAGE MAGGOT IN RADISH WITH VARIOUS INSECTICIDES OTTAWA, 1948

Treatment	Radish roots		
	Number examined	Number infested	Per cent* infested
BHC dust, .5% gamma isomer	308	30	9.7
Chlordane dust, 5%	436	43	9.9
Calomel—talc dust, 4%	459	58	12.6
Parathion dust, 5%	332	44	13.3
Calomel suspension, 1 oz. to 12 gal.	504	102	20.2
DDT dust, 3%	436	109	25.0
Mercury bichloride solution, 1 oz. to 10 gal.	435	113	26.0
Check—untreated	458	124	27.1

* Difference required for significance (P = .05) : 2.4.
(P = .01) : 5.1.

TABLE 3.—CONTROL OF THE CABBAGE MAGGOT IN RADISH WITH, AND INJURY TO FOLIAGE FROM, VARIOUS INSECTICIDES, OTTAWA, 1949

Material	Concentration	Insecticide injury to foliage	Radish roots		
			Number examined	Number infested	Per cent* infested
Parathion dust	2%	Very slight	428	44	10.3
BHC, 50% wettable powder	3 lb. to 80 gal.	Very slight	404	44	10.9
BHC dust	.5% g. isomer	Very slight	404	51	12.6
Chlordane, 50% wettable powder	3 lb. to 80 gal.	Very slight	465	82	17.6
Parathion, 15% wettable powder	2 lb. to 100 gal.	Very slight	566	102	18.0
Toxaphene dust	20%	Severe	410	81	19.8
Chlordane dust	5%	Very slight	446	123	27.6
Toxaphene, 40% wettable powder	2½ lb. to 80 gal.	Moderate	419	120	28.6
DDT, 50% wettable powder	2 lb. to 80 gal.	Very slight	456	166	36.4
Calomel suspension	1 oz. to 12 gal.	Very slight	389	148	38.0
DDD dust	5%	Severe	310	134	43.2
Mercury bichloride solution	1 oz. to 10 gal.	Very slight	341	152	44.6
Methoxychlor dust	5%	Very slight	445	206	46.3
DDT dust	5%	Severe	389	180	46.3
Check—untreated		None	428	215	50.2
Calomel—talc dust	4%	Very slight	388	211	54.4
DDD, 50% wettable powder	2 lb. to 80 gal.	Moderate	423	234	55.3
Methoxychlor, 50% wettable powder	2 lb. to 80 gal.	Very slight	428	256	59.8

* Difference required for significance (P = .05) : 2.4.
(P = .01) : 4.3.

TABLE 4.—CONTROL OF THE CABBAGE MAGGOT IN RADISH WITH, AND INJURY TO FOLIAGE FROM, VARIOUS INSECTICIDES, OTTAWA, 1950

Material	Concentration	Insecticide injury to foliage	Radish roots		
			Number examined	Number infested	Per cent* infested
BHC, 50% wettable powder	3 lb. to 80 gal.	None	496	27	5.4
Dieldrin, 25% wettable powder	4 lb. to 80 gal.	None	579	56	9.7
Heptachlor, 50% wettable powder	3 lb. to 80 gal.	None	547	53	9.7
Parathion, 15% wettable powder	2 lb. to 100 gal.	None	513	51	9.9
Chlordane, 50% wettable powder	3 lb. to 80 gal.	None	572	66	11.5
Lindane, 25% wettable powder	12 oz. to 80 gal.	None	622	72	11.6
Aldrin, 25% wettable powder	4 lb. to 20 gal.	None	527	70	13.3
Toxaphane, 40% wettable powder	2½ lb. to 80 gal.	Slight	620	137	22.1
Mercury bichloride solution	1 oz. to 10 gal.	None	551	154	27.9
Calomel suspension	1 oz. to 12 gal.	None	600	180	30.0
Dilan, 25% emulsion	1 pint to 100 gal.	Slight	563	200	35.5
Calomel—talc dust	4%	None	581	222	38.2
Check—untreated		None	583	242	41.5
Karathane, 25% wettable powder	4 lb. to 80 gal.	Severe	344	205	59.6

* Difference required for significance (P = .05) : 2.3.
(P = .01) : 3.9.

In 1949, six insecticides, namely, parathion dust, BHC wettable powder, BHC dust, chlordane wettable powder, parathion wettable powder, and toxaphene dust, gave good to moderate protection from the maggots, 79 to 61 per cent improvement over the untreated check. Chlordane dust and toxaphene wettable powder were less effective, giving 45 and 43 per cent control. The remaining materials gave poor results.

In 1950, wettable powder suspensions of BHC, dieldrin, heptachlor, parathion, chlordane, lindane, and aldrin gave very good to moderate control, 87 to 68 per cent improvement over no treatment. Toxaphene wettable powder was less effective, giving 47 per cent control. The remaining materials were relatively ineffective.

Certain of the chemicals were strongly toxic to radish. BHC as a dust caused 32 per cent reduction in yield in 1948. BHC as a drench caused 31 per cent reduction in yield in 1950 and produced atypical roots; of 496 bulbous roots examined in 1950, 44 per cent were hour-glass-shaped, being deeply constricted at the middle. Toxaphene dust caused severe scorching of the leaves and 37 per cent reduction in yield; toxaphene wettable powder caused moderate foliage injury in 1949, slight foliage injury in 1950. As a 5 per cent dust in 1949, DDT caused severe scorching of the leaves and 36 per cent reduction in yield. All the materials tested in 1949 caused at least very slight injury to the leaves, indicating that radish foliage is rather easily injured by insecticides.

A flavour-rating test in 1950 indicated that BHC caused strong tainting of the radish roots; lindane, slight tainting.

DISCUSSION

The chlorinated hydrocarbons as a group, and parathion, are not generally recommended for the control of insects attacking the roots of cruciferous crops in Canada. It is not the writers' purpose in this paper to recommend or suggest their use on radish; for radish matures so rapidly that in a control program of two applications the second application would be made only a few days before harvest.

Radish has definite advantages as a test plant for studies on the chemical control of root maggots. Dills and Odland (2) pointed out that the toxicities of insecticides to root maggots can probably be more accurately measured by using radish than cabbage. Experience at Ottawa, Ontario, has shown that radish is more likely to yield significant results than cabbage in a light infestation of the insect. The radish is seeded in the test area, whereas the cabbage is usually transplanted. Only a very small experimental area is required and the entire test may be completed in 5 to 6 weeks from the date of sowing, freeing the land for other use. It takes less work to apply the insecticides, and the phytotoxicity of the materials is more easily noted in radish than in cabbage. On the other hand, radish matures suddenly, requiring an almost overwhelming rush of records for 3 or 4 days. Also, insecticides that are effective for radish may not necessarily be effective for cabbage.

SUMMARY

Of 15 chemicals tested as drenches or dusts for toxicity to root maggots at Ottawa, 1948–50, radish being used as test plant, the best 9 treatments were effective in the following order, giving 83 to 66 per cent control: BHC, heptachlor, dieldrin, lindane, and parathion wettable powders, BHC dust, chlordane wettable powder, aldrin wettable powder, and parathion dust. The remaining materials, including calomel and mercury bichloride, the insecticides at present recommended for the control of the cabbage maggot attacking radish in Ontario, were unsatisfactory.

BHC, toxaphene and DDT dusts, and BHC wettable powder were strongly phytotoxic; toxaphene wettable powder, slightly phytotoxic. BHC, and to a lesser degree, lindane, tainted the radishes. *H. brassicae* was the species chiefly responsible for the damage to the plants.

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ANTIBIOTICS AND OTHER CHEMOTHERAPEUTIC AGENTS IN THE CONTROL OF BEE DISEASES[1]

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During the past few years, research work on bee diseases, a co-operative project between the Apiculture Division, Experimental Farms Service, and the Division of Bacteriology and Dairy Research, Science Service, has been devoted almost exclusively to the problem of sulpha drugs and antibiotics in relation to American foulbrood (6, 8, 9). Two years ago, investigations were begun also on the control of other bee diseases such as sacbrood, a virus disease of larvae, and Nosema, a protozoan disease of adult bees. The results of these studies are presented in this paper.

American Foulbrood

Apiary experiments were continued during the summers of 1950 and 1951 with antibiotics and other substances along the lines described elsewhere (8). Larger doses than previously were used. In addition, tests on spore survival in soil were continued, it having been shown earlier that spores in moist soil for 7 months were not inactivated. The results of the 1950 experiments were summarized in Table 1. AFB was not controlled with penicillin, chloromycetin, subtilin or the quaternary ammonium compound Hyamine 1622. It was controlled by aureomycin, although after 45 days two cells were found with AFB, showing that prevention was not complete; however, it is possible that secondary infection occurred since other experiments with AFB were also under way in the apiary. AFB spores retained in moist soil for 19 months are still not entirely inactivated; nevertheless, the low degree of infection indicates that their number or virulence has decreased.

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Table 1.—Effect of antibiotics and a quaternary ammonium compound on American foulbrood and on Sacbrood in the apiary[1]

Treatment (per gallon 50% sugar syrup containing about 1 billion AFB spores)		Examination of Colonies			
		16 days		31 days	
		AFB	Sacbrood	AFB	Sacbrood
Penicillin (procaine)	750,000 units	++	+	+++	+
Chloromycetin	0.5 grams	++	−	+++	−
Subtilin	0.5 grams	++	+	+++	+
Aureomycin	0.25 grams	−	+	−	−
Hyamine 1622	0.5 grams	+++	+	+++	+
Control		+++	++	+++	−
Spores from soil (19 months)		−		+	

[1] −, no infection
+ to +++, increasingly severe infection.

TABLE 2.—BACTERIOSTATIC EFFECT OF NEOMYCIN AND TERRAMYCIN ON ORGANISMS ASSOCIATED WITH FOULBROOD DISEASES OF BEES[1]

Active Material	*Bacillus larvae*		*B. alvei*		*B. para-alvei*	
	Strain		Strain		Strain	
	III	NW4	179	343	316	551
Neomycin	320	160	320	160	160	160
Terramycin	20,000	10,400	640	320	80	80

[1] Reciprocals of dilutions in thousands causing complete inhibition of growth in 24 hours.

TABLE 3.—EFFECT OF ANTIBIOTICS AND SULPHADIAZINE ON AFB IN THE APIARY[1]

Treatment (per gallon 50% sugar syrup containing about 1 billion AFB spores)	Examination of Colonies		
	28 days	43 days	78 days
Terramycin 0.25 grams	−	−	−
Neomycin 0.5 grams	−	−	+
Aureomycin 0.25 grams	+	+	+
Sulphadiazine 0.5 grams	−	−	−
Control	+++	+++	+++
Spores from soil (31 months)	−	−	−

[1] −, no infection;
+ to +++ increasingly severe infection.

Aureomycin warranted further study with regards to control of AFB, as it is of very low toxicity and readily available; on the other hand, it is expensive and not very stable as compared with sulpha compounds. Two more antibiotics have recently been described—neomycin and terramycin. These were tested *in vitro* against two strains each of *B. larvae*, *B. alvei*, and *B. para-alvei* as was done with other antibiotics (8). The data in Table 2 show terramycin to be very effective against *B. larvae*—slightly better even than penicillin in vitro (8), but much less effective against the remaining cultures, analogous to the effect of aureomycin (8). It is interesting that with both of these antibiotics the two strains of *B. para-alvei* are the least sensitive. Neomycin has the same order of activity as streptomycin (8). These two substances along with aureomycin and sulphadiazine were tested in the apiary during the summer of 1951, with results as summarized in Table 3. It will be noted that only colonies receiving terramycin or sulphadiazine were free from disease whereas those with neomycin or aureomycin were not. Thus another compound—terramycin—shows promise in the practical control of AFB. It is of considerable interest to note that this antibiotic may also control European foulbrood (11). AFB spores added to soil were no longer virulent after 31 months. At the same time the above experiment was initiated, 6 frames with eggs and young larvae were sprayed with a heavy spore suspension and one side of each sprayed with one of the following compounds: terramycin, aureomycin, neomycin, chloromycetin, streptomycin and sulphadiazine. The frames were then placed in one colony. No disease developed, confirming the possibility of control by spraying, suggested by Haseman (5).

In the summer of 1950 an experiment was started also on the stability of sulpha drugs in honey. Sulphathiazole, sodium sulphathiazole and sulphadiazine were each added to 20 pounds of honey in 2.0 gram amounts and mixed thoroughly. In the summer of 1951, 5 pounds of each mixture were removed, diluted with an equal amount of water, inoculated heavily with AFB spores and fed to bees, one colony being employed for each compound. No disease developed after 78 days, indicating that these substances retained their activity after one year in honey, thus explaining, in part, the observations that one treatment of a colony with sulpha drugs may be effective for several seasons.

Bacillus pulvifaciens (n. sp.)

This organism was isolated from dead larvae in comb obtained from Alberta and was found to be a new species (7). Preliminary trials at that time showed that it was not infectious. This work was repeated on a more elaborate scale with spore suspensions from powdery scale (which were both fed and sprayed) and with suspensions from 7-day-old agar cultures. No infection occurred during the entire summer, indicating that this bacillus is not pathogenic to the honeybee.

Sacbrood

Although this virus disease is not particularly serious in an apiary, quite a number of larvae are frequently killed by it in spring and early summer (17). In view of the reports on successful treatment of certain virus diseases with chloromycetin and aureomycin (12), experiments were initiated to determine their effect on sacbrood. In the summer of 1949, three colonies of bees were each fed 1 gallon of 50 per cent sugar syrup inoculated with a heavy suspension of crushed infected larvae; one colony received 200 mg. of aureomycin, one received 200 mg. of chloromycetin, and one was left as control. No disease developed in either of the colonies receiving antibiotics but abundant infection occurred in the control. However, as the colony with aureomycin had lost its queen and raised few larvae, absence of sacbrood in it was perhaps not due to the antibiotic.

In the second experiment, natural infection was encouraged and the effect of various substances observed with results as given in Table 1. Again chloromycetin was effective in controlling the virus, but not aureomycin nor any of the remaining substances. After 31 days the disease appeared to be on the wane as even the control had no sacbrood.

TABLE 4.—INFLUENCE OF CHLOROMYCETIN AND AUREOMYCIN ON SACBROOD IN THE APIARY[1]

Treatment	Examination for sacbrood after 48 days
Sacbrood inoculum alone	+
Sacbrood inoculum after filtration through Seitz filters	++
Sacbrood inoculum heated 10 minutes at 80° C.	−
Inoculum + Chloromycetin, 200 mg. per gallon syrup	−
Inoculum + Chloromycetin, 100 mg. per gallon syrup	−
Inoculum + Aureomycin, 200 mg.	+++
Inoculum + Aureomycin, 100 mg.	+

[1] −, no infection
+ to +++, increasingly severe infection.

A more elaborate experiment was then set up with inoculated colonies in 1950 as shown in Table 4. It is clear again that chloromycetin exerted complete control whereas aureomycin did not. Filtration of the inoculum through sterile Seitz filters permitted the virus to pass as White has demonstrated with Berkfeld and Pasteur-Chamberland candles (17). However, when chloromycetin was fed to a colony which was badly infected, it did not cure it. Thus, results of three separate tests show that chloromycetin may prevent development of sacbrood in a colony. White (17) found that neither carbolic acid nor quinine prevented development of sacbrood in his colonies. Others (2) have shown sulpha drugs to be ineffective.

During the summer of 1951, chloromycetin and terramycin were tested on colonies in triplicate, both by feeding in artificially infected sugar syrup and by spraying comb previously sprayed with a heavy suspension of larvae infected with sacbrood. Curiously no control was achieved with either antibiotic; in fact all the colonies were quite heavily infected with what appeared at the outset to be sacbrood. However, on the second and third examination the dead larvae had not yet been removed and had become dark and shrivelled. This is not characteristic of typical sacbrood; consequently it is possible that another disease (non-bacterial) had infected these colonies or another strain of sacbrood had developed which was resistant to chloromycetin. This problem requires further investigation.

Nosema Disease

As early as 1919 White (18) reported that certain compounds such as betanaphthol and salol were effective in controlling Nosema when fed to bees in diluted, inoculated honey, but that eucalyptus and quinine were not. Since that time, numerous other substances including antibiotics, sulpha drugs, arsenicals and antiprotozoan agents have been tried in vain (1, 4, 14, 15). Carbarsone (an arsenical compound) at the rate of 0.25 per cent inhibited Nosema in caged bees but shortened their life; when fed in sugar syrup at the rate of 0.05 per cent to colonies it had no effect (16).

Similar experiments were carried out in 1950 with a variety of substances which were dissolved or suspended in 60 per cent sugar syrup in 2-oz. bottles with perforated screw caps and fed to bees in wire cages, each of which contained 100 adult bees. Bees of uniform age were obtained for these studies by transferring several frames of capped brood, free of adhering bees, to an incubator. After a 24-hour period young bees had emerged and were available for the cages. From the data shown in Table 5 it is evident that most of the compounds tested were toxic in the concentrations used; sulphametizine and diodoquin were not. The compounds listed were then fed to bees in syrup containing 30 to 50 million Nosema cysts freshly removed from infected bees. The amount of each substance used was slightly lower than that shown to be toxic. The death rate of the bees in some of the cages indicated that the substances fed to them were still toxic (emetine, streptomycin, ceepryn). Dead bees were removed from the cages each day, dissected and examined for the presence of cysts of the parasite. The procedure used in preparing a specimen for examination consisted of removing the alimentary tract and detaching the ventriculus from the small intestine. To avoid possible contamination with cysts from the frequently ruptured rectum the ventriculus was washed in distilled water and tissue from the anterior end used for microscopical examination.

TABLE 5.—TOXICITY OF CERTAIN ANTIBIOTICS, SULPHA DRUGS AND ANTI-PROTOZOAN AGENTS TO BEES

Chemical	%	Per cent kill after (days)				
		3	6	9	12	15
Streptomycin	0.1	0	34	—	70	—
Aureomycin	0.10	4	6	8	27	47
	0.40	42	68	100	—	—
Sulphametazine	0.02	2	9	11	16	28
	0.10	5	13	16	18	22
Atabrine	0.05	2	5	8	26	49
	0.20	20	71	76	100	—
Paludrine	0.05	2	23	67	75	100
	0.20	13	71	100	—	—
Carbarsone	0.05	1	73	77	100	—
	0.2	3	28	54	72	100
Emetine	0.004	0	1	3	19	50
	0.02	19	22	36	73	100
Ceepryn (QAC)	0.008	0	16	36	55	63
	0.04	13	59	65	100	—
Chiniofon	0.1	0	6	21	28	51
	0.4	1	3	45	100	—
Diodoquin[1]	0.1	0	2	5	5	10
	0.4	6	6	10	12	17
Control		8	9	9	12	22

[1] Insoluble.

The presence of epithelial cells packed with cysts was the criterion used for diagnosis. In the cages receiving emetine, streptomycin and ceepryn and in those receiving atabrine, paludrine and chiniofon, there was a higher incidence of infected bees than in the cages with inoculum only (percentage mortality of infected bees at 12 days: inoculum, 35 per cent; emetine, 88 per cent; streptomycin, 72 per cent; ceepryn, 65 per cent; atabrine, 64 per cent; paludrine, 59 per cent; chiniofon, 51 per cent), suggesting that the resistance of the bees may have been lowered by these chemicals. These experiments were repeated with certain of the compounds and with the addition of chloromycetin and sulphaquinoxaline. The results in Table 6 indicate that only the latter compound showed an appreciable theraupeutic effect over a period of 12 days; chloromycetin may also be of some promise.

In 1951 further experiments were carried out with the amebicides, chloroquine, carbarsone oxide as well as with sulphaquinoxaline and fumagillin, a recently discovered amebicidal agent (13). Neither of the first two compounds was effective in controlling Nosema and both were slightly toxic to the bees. Sulphaquinozaline reduced infection but not to the extent as to be considered of practical importance. Fumagillin appeared highly promising as indicated elsewhere (10).

TABLE 6.—EFFECT OF CERTAIN COMPOUNDS ON INFECTION OF BEES WITH *Nosema apis*

Chemical	%	Per cent dead bees showing light or heavy Nosema infection	
		6 days	12 days
Control		1	1
Inoculum only		39	69
Sulphametazine	0.2	49	75
Sulphametazine	0.4	28	59
Sulphaquinoxaline	0.2	14	33
Sulphaquinoxaline	0.4	15	38
Diodoquin	0.4	20	60
Aureomycin	0.05	30	55
Chloromycetin	0.05	22	48

DISCUSSION

The ever-increasing number of new antibiotics and drugs offers research workers on bee diseases a constant supply of test-substances. A variety of sulpha drugs may now be used to control AFB in an apiary and it is probable that one or more of the newer antibiotics such as terramycin may also be found satisfactory. Haseman (5) has reported that penicillin or streptomycin may be used successfully but involve too much care and labour. At present these newer compounds may be expensive but their potency and low toxicity are a decided advantage over sulpha drugs. There is reason to hope too that some of these substances may be of value in controlling EFB as well (11); sulpha drugs do not appear to be useful in this connection (2, 3).

The control of certain animal virus diseases with antibiotics such as chloromycetin, aureomycin and terramycin stimulated experiments with these substances on control of sacbrood. Evidence was obtained that chloromycetin might do this in the apiary. Sacbrood is not of serious concern to beekeepers, but it is interesting that this virus may be inhibited by an antibiotic active against virus pneumonia and ricketstial diseases. It would also be of interest to determine if bee paralysis is amenable to treatment with one of these anti-viral agents.

Few diseases of bees have been studied so extensively and with so little success, chemotherapeutically, as Nosema. Almost every known anti-malarial or anti-amebic substance has been tested but has been found to be either toxic or without effect on the disease. For this reason sulphaquinoxaline appears to have possibilities; chloromycetin too, will have to be re-examined in the light of the preliminary results obtained. The antibiotic fumagillin appeared to be the most promising of all the substances tested and large-scale experiments with this compound are in progress.

SUMMARY

Penicillin, chloromycetin, subtilin, neomycin and Hyamine 1622 did not control AFB in the apiary when fed in 50 per cent sugar syrup containing AFB spores. Aureomycin suppressed this disease markedly for a time after which several AFB cells were observed; terramycin and sulphadiazine exerted complete control during the entire season.

AFB spores remained viable for at least 19 months in moist soil at room temperature.

Sulpha drugs dissolved in honey for one year still retained their activity against AFB in the apiary.

Bacillus pulvifaciens was found to be non-pathogenic to bees.

Chloromycetin, when fed in 50 per cent sugar syrup at the rate of 100 to 200 mg. per gallon, prevented development of sacbrood in 3 out of 4 tests.

Many substances, such as antibiotics, sulpha drugs and anti-protozoan agents, were tested against *Nosema apis* in caged bees. Most of these compounds were either toxic or ineffective; sulphaquinoxaline and chloromycetin exerted an appreciable inhibitory effect on Nosema; fumagillin was the most promising substance tried.

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THE EFFECT OF WIND ON THE UNIFORMITY OF WATER DISTRIBUTION BY SOME ROTARY SPRINKLERS[1]

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LITERATURE REVIEW

The uniformity of water distribution by sprinklers has received the attention of several workers. In 1930, Staebner (7) reported on a study conducted to obtain comparative efficiencies in distribution of American and German spray equipment. Powers and Bertramson (3), in 1939, presented the results of a study on low pressure sprinkler systems, including the Rain Bird sprinkler. They found that a 60- by 60-foot staggered or triangular spacing applied the water more uniformly than the 40- by 60-foot spacing, at little or no wind. Schoenleber (6) investigated the uniformity of distribution by 4 types of sprinklers with particular reference to small garden areas. He determined the uniformity coefficients for each sprinkler on the basis of no overlap. In 1947, Wilcox and Swailes (8) reported the results of a study on the uniformity of water distribution by some under-tree orchard sprinklers at little or no wind. The purpose of their study was to compare the distribution pattern of the common sprinklers in use at various pressures and spacings. They concluded that pressures of 20 to 30 pounds appeared satisfactory and that square spacing produced higher uniformity coefficients than rectangular spacing, when similar areas were compared. Christiansen (2), in 1942, presented the results of an extensive study on the uniformity of application by several commercial sprinklers. He studied the effect of wind, speed of rotation, and spacing of sprinklers upon the distribution. His conclusion on the effect of wind was: "Although the patterns appear very uneven, the effect of wind on the uniformity of distribution over a larger area, with sprinklers close enough together to provide an adequate overlap, is less serious than unevenness from other causes, such as variation in rate of rotation, because with wind the local areas of high and low concentration always occur at the same relative position with respect to the sprinklers and do not overlap on themselves and produce an exaggerated effect".

Staebner (7), Powers and Bertramson (3), and Schoenleber (6) based the relative merits of the various sprinkler irrigation equipment on the basis of no overlap. Christiansen (2), Wilcox and Swailes (8), attacked the problem of distribution on the basis of overlap which has become general practice. They obtained the distribution pattern of individual sprinklers by collecting the water in cans placed in a 5- by 5-foot pattern and then determining the uniformity coefficients for various spacings. Christiansen (2) determined the coefficient of uniformity on the basis of deviations from the mean while Wilcox and Swailes (8) used the squares of the deviations from the mean.

All previous studies on the distribution of water by sprinklers with the exception of Christiansen (2) have been conducted with little or no wind.

[1] Contribution from the Experimental Farms Service, Department of Agriculture, Ottawa.
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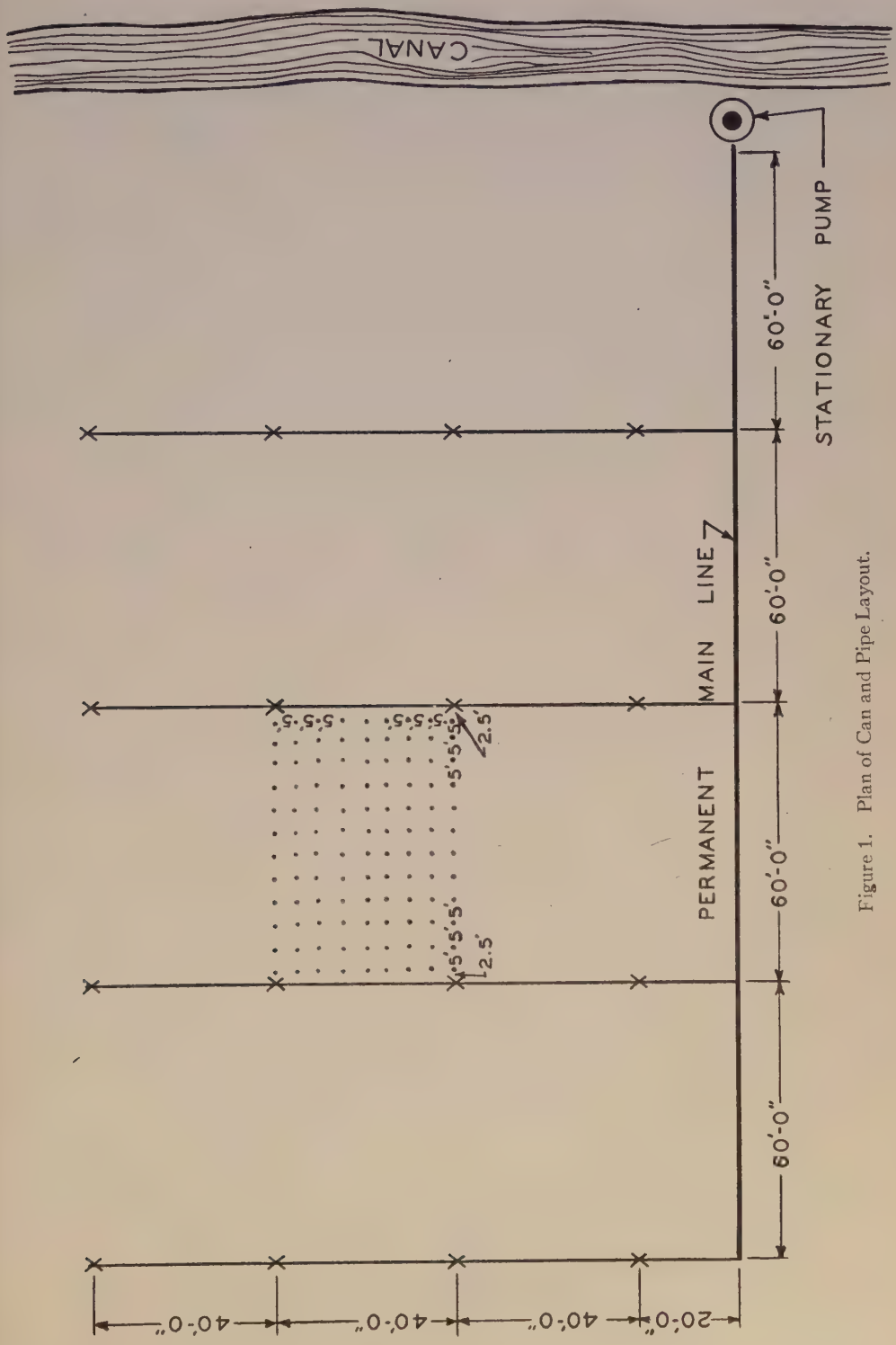
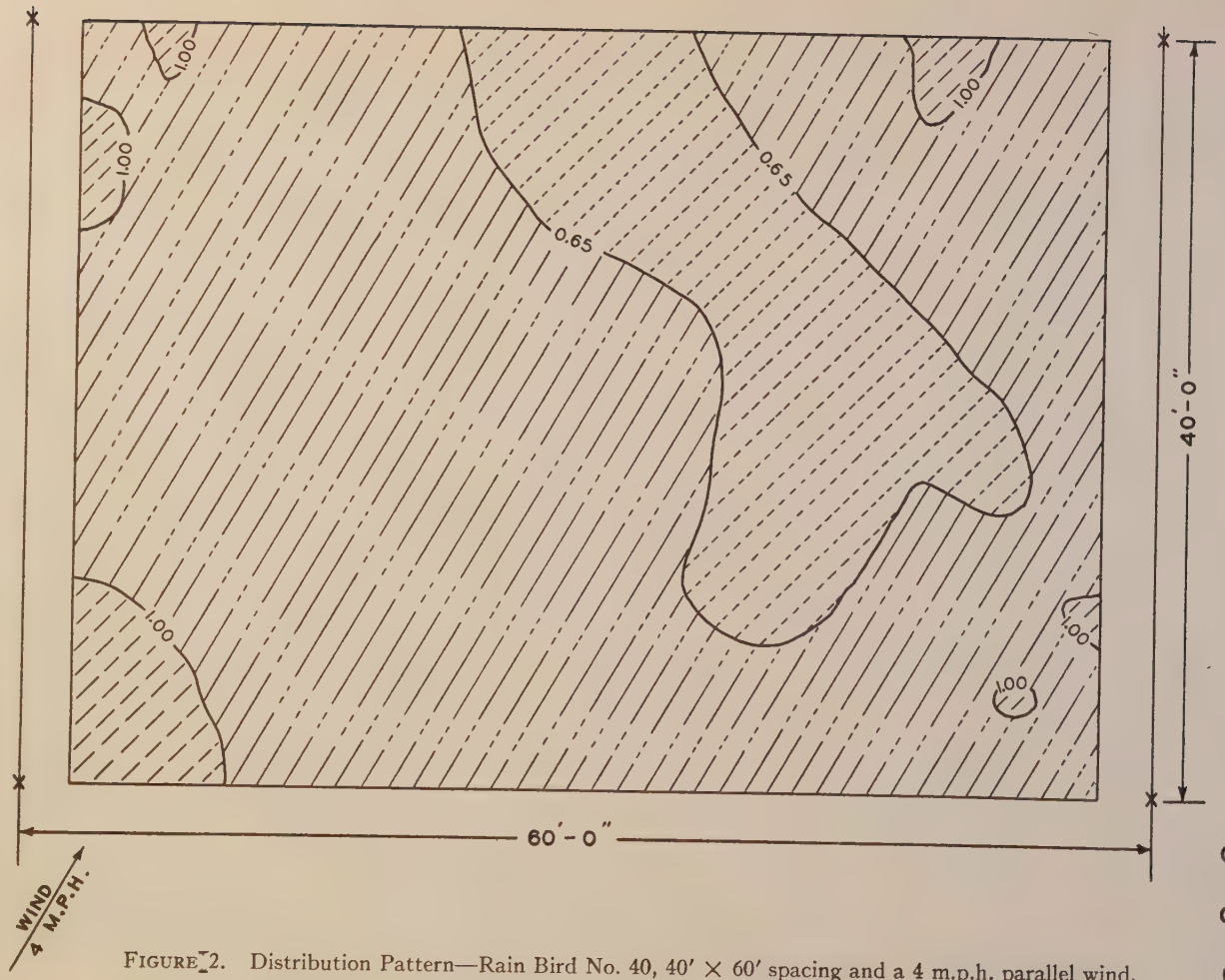


Figure 1. Plan of Can and Pipe Layout.



OCT. 31 / 50
RAINBIRD # 40
$\frac{3}{16}$" X $\frac{1}{8}$"
SPACING 40' X 60'
PRESSURE 35 P.S.I.
CU = 82

LEGEND
X - SPRINKLER
0.45 - 0.65
0.65 - 1.00
1.00 - 1.50

FIGURE 2. Distribution Pattern—Rain Bird No. 40, 40′ × 60′ spacing and a 4 m.p.h. parallel wind.

Christiansen, however, did not name the sprinklers used in his studies. Moreover, several new and modified sprinklers have been introduced since his study was conducted.

This study, therefore, was undertaken to determine the effect of wind on the uniformity of water application by some rotary sprinklers at various pressures aud spacings, starting with those recommended by the sprinkler manufacturers (1, 5) as a result of their routine tests to check the value of modifications in their sprinkler head design. This paper presents the results of one year's study.

PROCEDURE

A level area was chosen for the study which was cleared of all vegetation and then smoothed. The layout plan, as shown in Figure 1, included 4 sprinkler lines, with 4 sprinklers on each, with the test-site in the centre of the area bounded by 4 sprinklers. The reason for the lines and sprinklers, in addition to those immediately adjacent to the site, was to obtain a true picture of the water that would fall on the test area under actual field conditions. The 2 extra sprinklers per line were necessary because of the overlap. The additional lines were required when sprinkling during windy periods. The two centre lines were sufficient to give a true picture when sprinkling during little or no wind, but during periods of high winds the line on the windward side was required because of the shifting of the spray more than the distance between the lines.

The cans ($2\frac{7}{8}$ inches in diameter and $4\frac{3}{8}$ inches in depth) were placed on a 5-foot grid. The depth of water in each can, after a test run of two hours, was determined by measuring the volume of water in cubic centimetres and converting to depth in inches.

The wind direction was obtained by careful observation of a weather vane installed at the site. The wind speed was determined by using a "velometer" which was calibrated in the wind tunnel in the Soil Research Laboratory, Swift Current, Saskatchewan.

The sprinklers were operated at the recommended pressures and spacings under varying wind speeds and directions and the distribution patterns charted. An attempt was then made to improve the distribution by varying the spacings while sprinkling during periods of high wind.

The coefficient of uniformity was determined by applying the following formula from Wilcox and Swailes (8):

$$U = 100 - \frac{100\ SD}{M}$$

in which:

U = uniformity coefficient.
SD = the standard deviation of the total depths of water.
M = the mean of these depths.

Sprinklers Tested

Distribution patterns at varying pressures, nozzle sizes, and wind conditions, were obtained for the following:

Rain Bird 40 (4) at 40 × 60 and 50 × 50-foot spacings.
Rain Bird 40LA (4) at 40 × 40 and 50 × 50-foot spacings.
Rain Bird 40W (4) at 20 × 60-foot spacing.
Buckner 4176 (1) at 40 × 60-foot spacing.
Rain Bird 20 (4) at 40 × 40 and 20 × 40-foot spacings.
Rain Bird 20A 7° (4) at 20 × 40 and 20 × 20-foot spacings.

The Rain Bird 40 and Buckner 4176 are the common field sprinklers on the Prairies. They operate on the hammer action principle with slight differences in design. The Rain Bird 40LA (low angle) is the same as the Rain Bird 40 except for the nozzles and arm. The Rain Bird 40W (wind) is actually the Rain Bird 40 except that usually one nozzle is plugged and the spacing along the line is decreased. The Rain Bird 20 and 20A 7° are smaller sprinklers designed for garden and orchard irrigation. The Rain Bird 20A 7° is primarily used in undertree orchard irrigation.

RESULTS AND DISCUSSION

Distribution Patterns

A few distribution patterns are shown in Figures 2 to 9 inclusive. These were selected from a total of 54 tests. The depth of water collected in each can was plotted and the distribution pattern shows the resultant water level contour lines with the area between lines shaded to clarify the picture. The intervals chosen are less than 0.20, 0.20 to 0.30, 0.30 to 0.45, 0.45 to 0.65, 0.65 to 1.00, 1.00 to 1.50, 1.50 to 2.25, 2.25 to 3.4, and 3.4 to 5.1 inches. The interval chosen is based on a constant percentage increase.

In general, a pattern with few types of shading, or the majority of the area of one type, depicts a more uniform distribution than a pattern with several types of shading and irregular patterns. Distribution patterns as shown in Figures 2, 3, 4, and 8 are typical of the uniform water application obtained while sprinkling during periods of little or no wind.

The varied shading and irregular patterns as shown in Figures 5, 6, and 7 depict the erratic water distribution when sprinkling during periods of high winds. The detrimental effect of wind is clearly shown in Figure 7.

Note the concentration of water at each sprinkler. Note that the area of low application starts at the windward side midway between the two sprinklers and extends generally through the centre towards the leeward side. This pattern indicates a closer spacing is required because the desirable degree of overlap is not obtained on account of the detrimental effect of the wind.

Uniformity Coefficients

An attempt was made to obtain uniformity coefficients for the same sprinkler under similar conditions as a check and likewise for different sprinklers for comparison purposes. It was difficult, however, to obtain corresponding relationships because of fluctuating wind speeds and directions. Tables 1 and 2, therefore, list the few closely corresponding relationships obtained from a total of 54 tests. Table 1 includes the field sprinklers, e.g., Rain Bird 40, 40LA, and 40W, and the Buckner 4176.

The first general observation from Table 1 is that the coefficient of uniformity decreases as the wind speed increases. The average at a wind speed of 0 to 4 miles per hour is about 82 and at 17 miles per hour and over about 32. It is also noted that during calm periods all the sprinklers investigated gave very similar coefficients.

Due to fluctuating and unpredictable wind conditions close comparisons between the Buckner 4176 and Rain Bird sprinklers were not obtained.

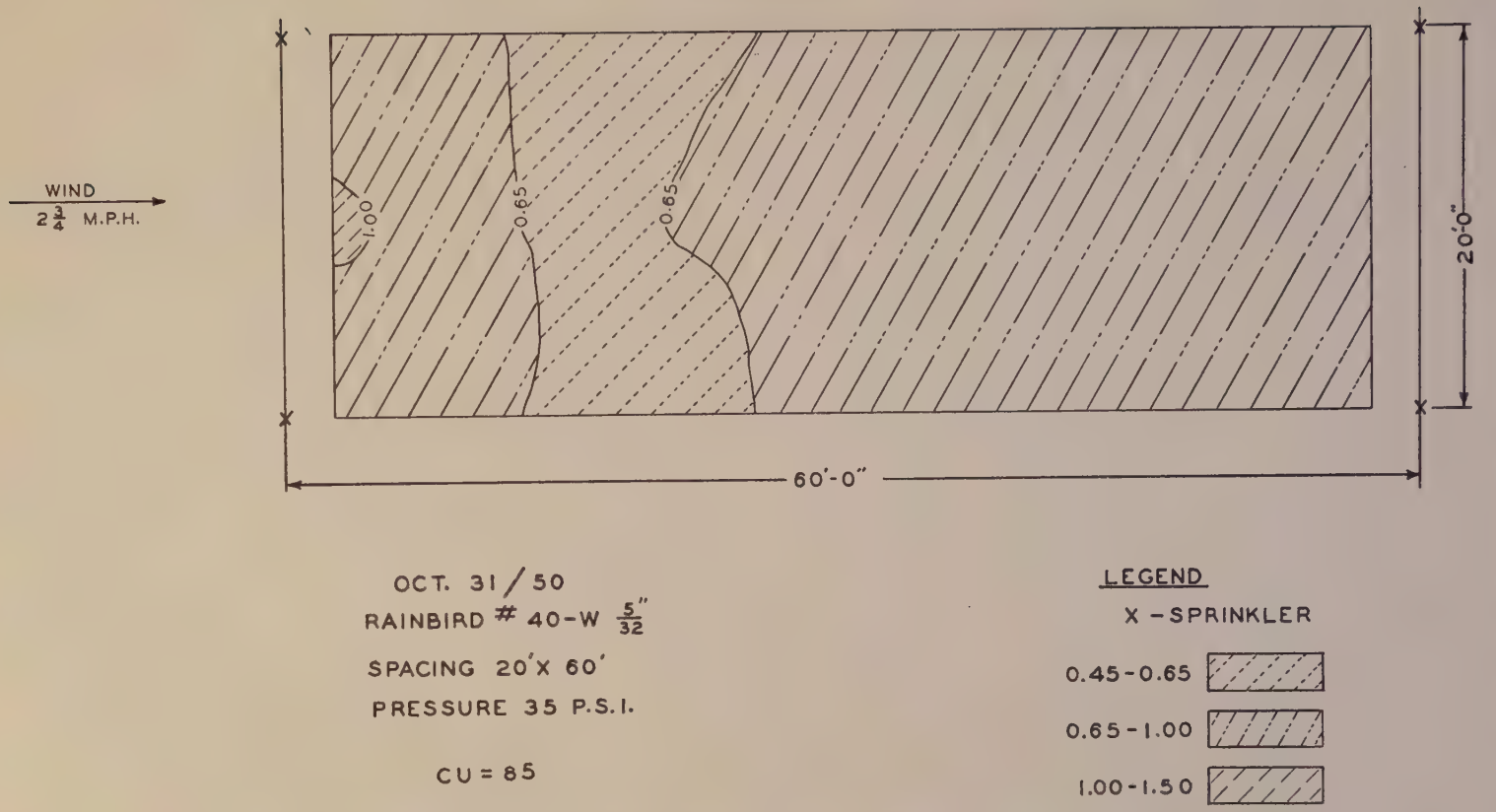


FIGURE 3. Distribution Pattern—Rain Bird No. 40W, 20′ × 60′ spacing and a right angle wind of 2¾ m.p.h.

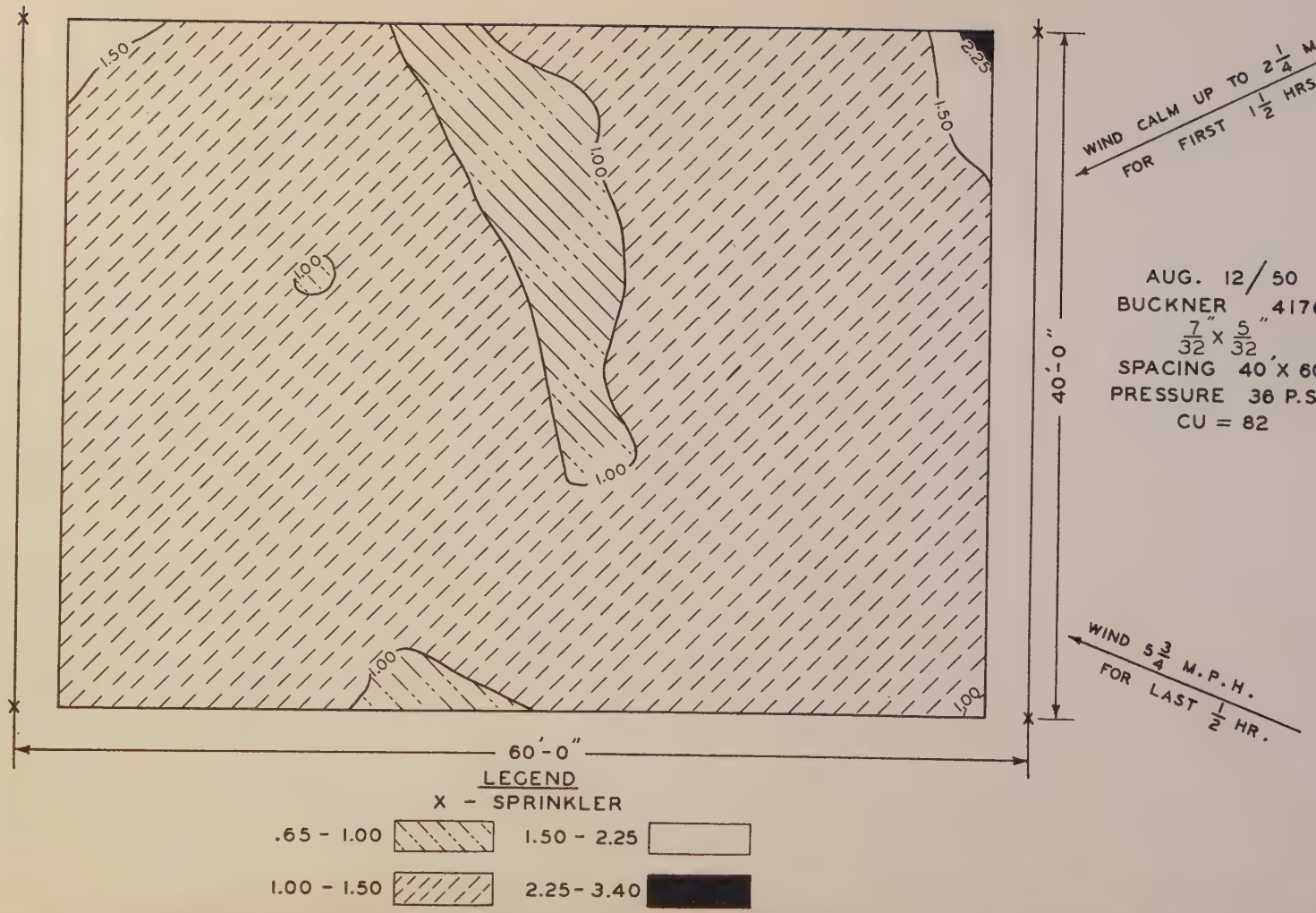


FIGURE 4. Distribution Pattern—Buckner No. 4176, 40′ × 60′ spacing and a variable wind of $2\frac{1}{4}$ to $5\frac{3}{4}$ m.p.h.

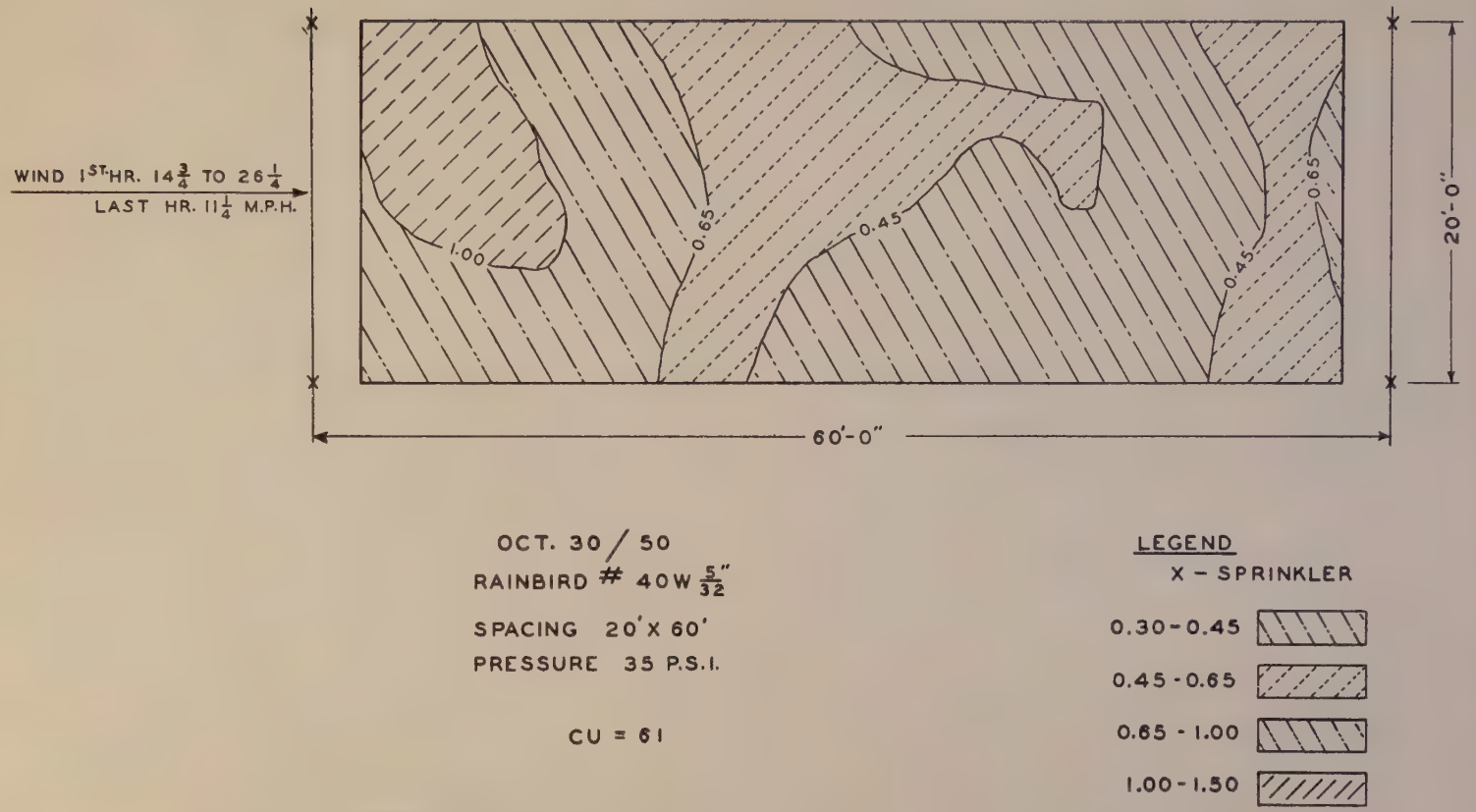


FIGURE 5. Distribution Pattern—Rain Bird No. 40W, 20′ × 60′ spacing and a right angle wind of 15 m.p.h.

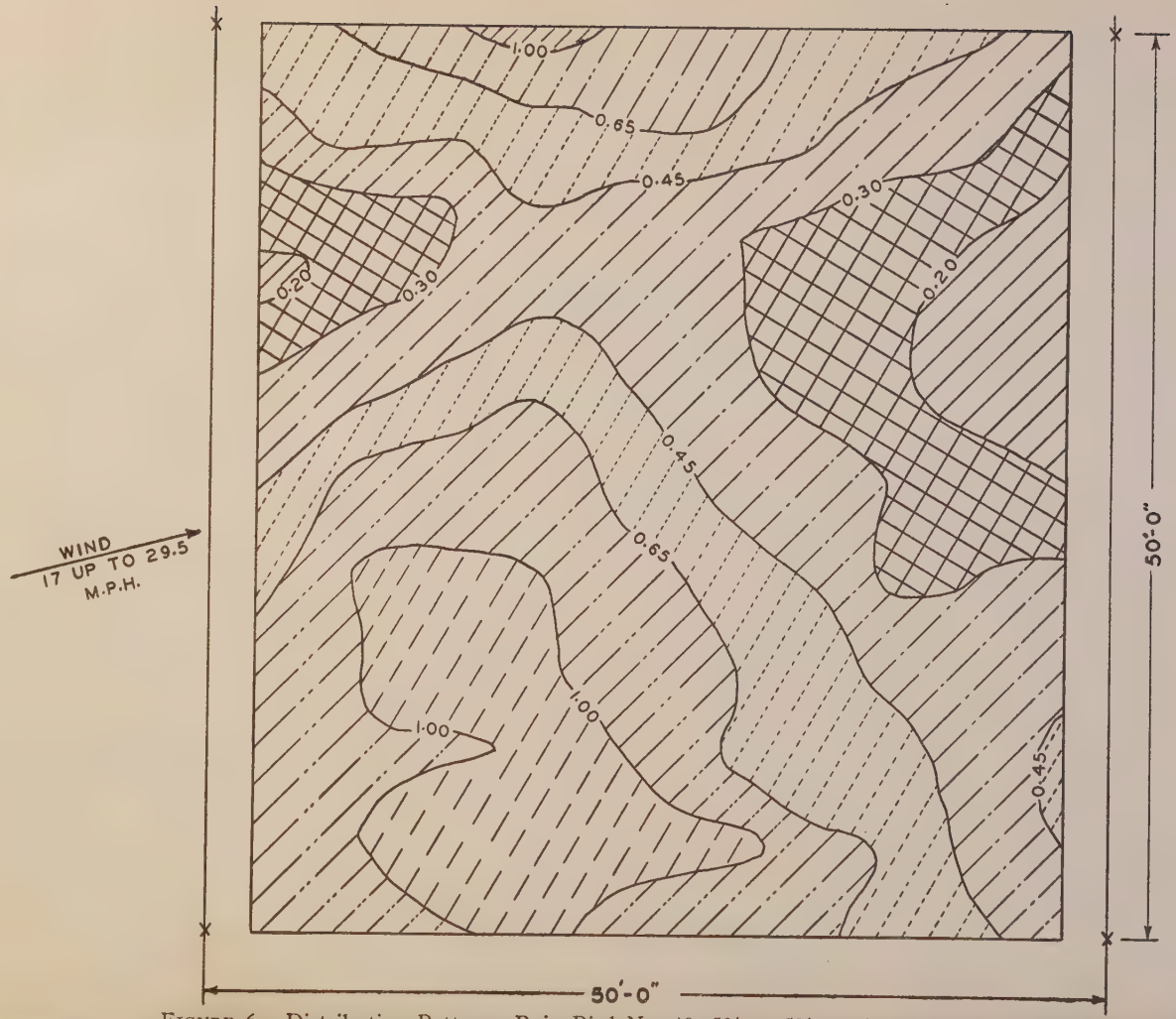


FIGURE 6. Distribution Pattern—Rain Bird No. 40, 50′ × 50′ spacing and a right angle wind of 17 to 29½ m.p.h.

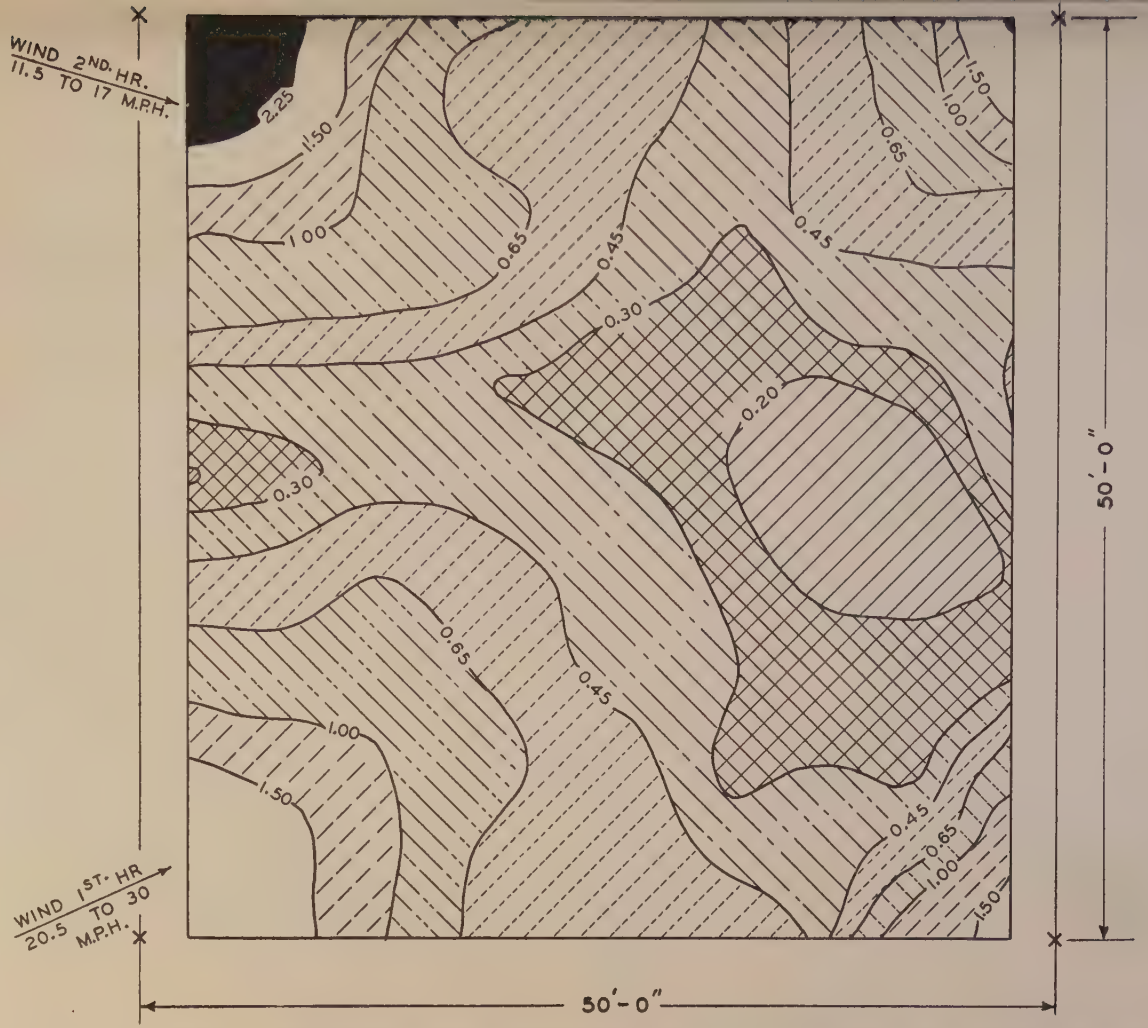


FIGURE 7. Distribution Pattern—Rain Bird No. 40LA, 50′ × 50′ spacing, at a variable wind from 11¼ to 30¾ m.p.h.

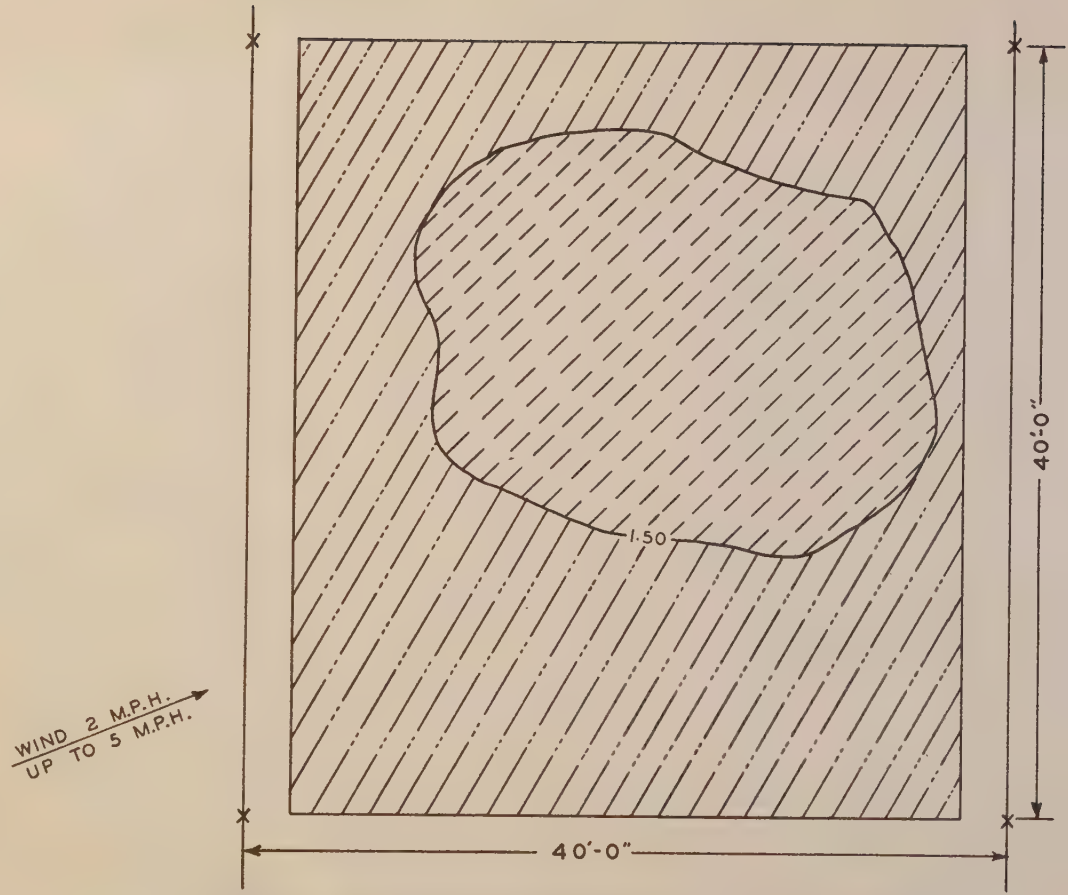


FIGURE 8. Distribution Pattern—Rain Bird No. 20, 40′ × 40′ spacing and a right angle wind of 2 m.p.h.

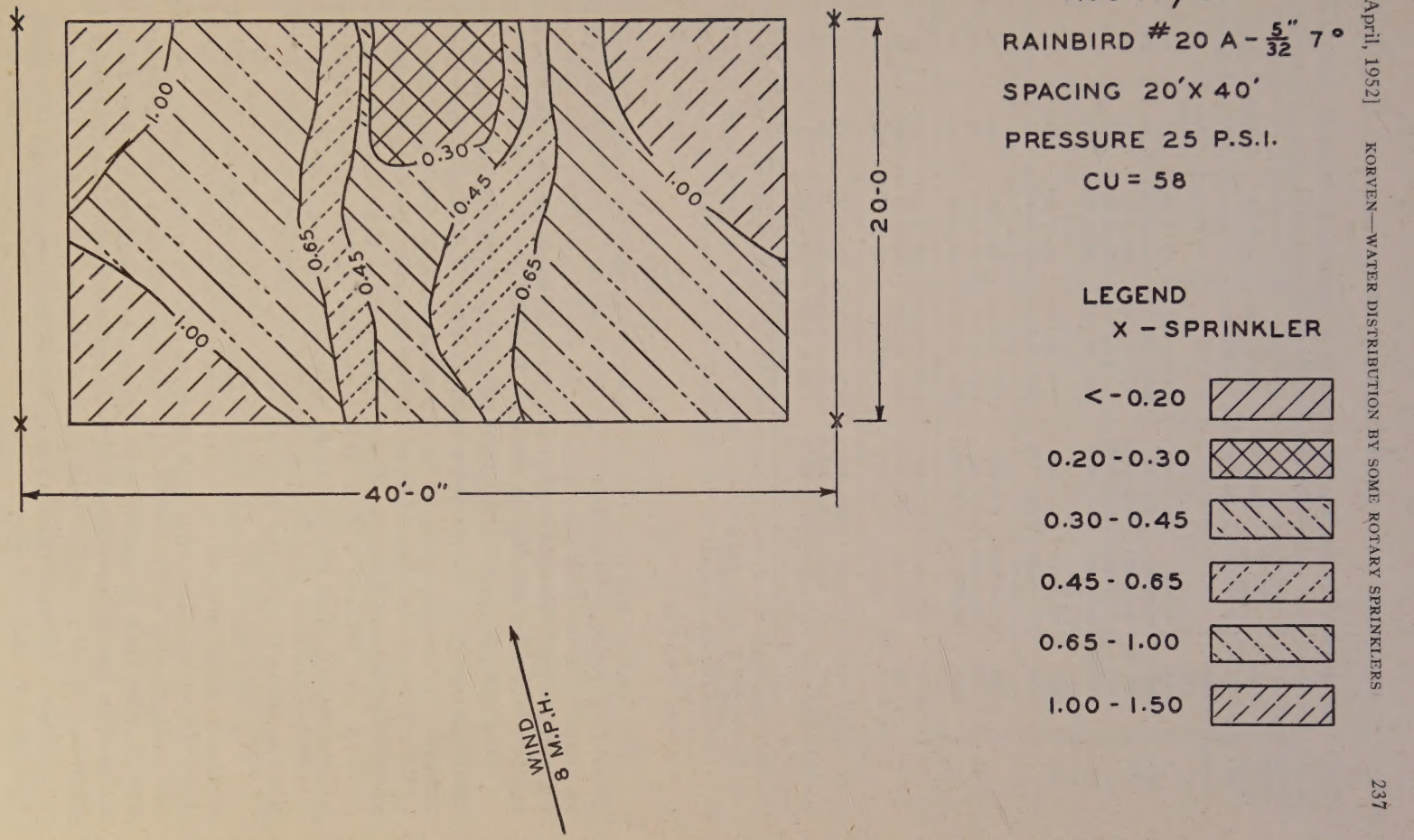


FIGURE 9. Distribution Pattern—Rain Bird No. 20A 7°, 20′ × 40′ spacing and an 8 m.p.h. parallel wind.

TABLE 1.—THE EFFECT OF WIND ON UNIFORMITY OF APPLICATION BY FIELD SPRINKLERS

Speed Range	Speed	General direction	Sprinkler[1]	Nozzle size	Spacing	Pressure	Cu[2]
m.p.h.	m.p.h.			in.	ft.	p.s.i.	
	4.00	Parallel	R.B. 40	3/16 × 1/8	40 × 60	35	82
	Calm	Parallel	R.B. 40	3/16 × 1/8	50 × 50	35	81
0–4	0–2.75	Rt. Angle	R.B. 40LA	1/4 × 7/32	40 × 40	35	80
	2.75	Rt. Angle	R.B. 40W	5/32	20 × 60	35	85
	0–2.25[3]	45° Angle	Buc. 4176	7/32 × 5/32	40 × 60	35	82
5–8	5.75	Rt. Angle	R.B. 40LA	1/4 × 7/32	40 × 40	40	72
	6.50	Rt. Angle	Buc. 4176	7/32 × 5/32	40 × 60	35	60
	11.50	Rt. Angle	R.B. 40	13/64 × 5/32	40 × 60	35	64
9–12	8–14.75	Rt. Angle	R.B. 40	3/16 × 1/8	50 × 50	35	63
	9.00	Parallel	R.B. 40LA	3/16 × 5/32	40 × 40	40	65
	14.75	45° Angle	R.B. 40	3/16 × 3/32	40 × 60	30	51
13–16	12.50	45° Angle	R.B. 40LA	3/16 × 5/32	50 × 50	35	19
	14.75–26.25[4]	Rt. Angle	R.B. 40W	5/32	20 × 60	35	61
	17–29.50	45° Angle	R.B. 40	3/16 × 1/8	50 × 50	35	48
17	17.00	45° Angle	R.B. 40LA	3/16 × 5/32	50 × 50	35	33
and over	11.25–17.00[5]	45° Angle	R.B. 40LA	3/16 × 5/32	50 × 50	35	15

[1] R.B.—Rain Bird.
Buc.—Buckner.
[2] Cu—Coefficient of Uniformity.
[3] 5.75 m.p.h. for last half hour.
[4] 11.25 m.p.h. for last hour.
[5] 20.50–30.75 m.p.h. for last hour.

The Buckner and Rain Bird 40 sprinklers applied the water with equal uniformity during calm periods. The low coefficient for the Buckner 4176 as compared to the Rain Bird 40LA in the speed range 5 to 8 miles per hour is not due to the difference in sprinkler, but is probably because of the higher pressure and closer spacing for the Rain Bird 40LA.

The low trajectory of the Rain Bird 40LA did not prove superior to the high trajectory of the Rain Bird 40 when sprinkling during windy periods. In the speed range of 9 to 12 miles per hour, spacings of 50 × 50 and 40 × 60 for the Rain Bird 40, and 40 × 40 for the Rain Bird 40LA, produced similar coefficients. At the higher speed of 13 to 16 miles per hour, the Rain Bird 40LA at a 50 × 50-foot spacing did not apply the water as uniformly as the Rain Bird 40 at a 40 × 60-foot spacing. The Rain Bird 40 was superior to Rain Bird 40LA at the same spacings of 50 × 50 feet during wind speeds of 17 miles per hour and over.

The Rain Bird 40W with the wind blowing across the line at a 20 × 60-foot spacing produced a higher coefficient than the Rain Bird 40 at 40 × 60-foot spacing during wind speeds of 13 to 16 miles per hour. Again due to fluctuating wind conditions, attempts to obtain a uniformity coefficient for the Rain Bird 40W with a wind blowing along the line did not materialize, but it is predicted that the coefficient would be considerably lower.

Table 2 includes the results obtained from the smaller sprinklers, Rain Bird 20 and 20A 7°.

TABLE 2.—THE EFFECT OF WIND ON UNIFORMITY OF APPLICATION BY RAIN BIRD 20 AND 20A 7°

Speed Range	Speed	General direction	Sprinkler	Nozzle size	Spacing	Pressure	Cu[1]
m.p.h.	m.p.h.			in.	ft.	p.s.i.	
0–4	0–2.00[2]	Parallel	20	7/32	40 × 40	30	86
	0–6.75	Rt. Angle	20A 7°	3/16	20 × 40	25	74
5–8	7.50	Rt. Angle	20	5/32	20 × 40	35	77
	8.00	Parallel	20A 7°	5/32	20 × 40	25	58
	6.75	45° Angle	20	7/32	40 × 40	35	73
9–12	9.75	Rt. Angle	20	7/32	20 × 40	25	64
	9.00	45° Angle	20A 7°	3/16	20 × 40	25	55
13 and over	15.25–19.00	Parallel	20	5/32	40 × 40	25	46

[1] Cu—Coefficient of Uniformity.
[2] Few gusts to 5 m.p.h.

The Rain Bird 20 with its high trajectory applied the water more uniformly than the Rain Bird 20A 7° (low angle) at wider spacings up to wind speeds of 8 miles per hour. The Rain Bird 20 produced a higher coefficient than the Rain Bird 20A (64 as compared to 55) at similar spacings of 20 × 40 at winds of 9 miles per hour. A spacing of 40 × 40 is too wide for the Rain Bird 20 at a 15- to 19-mile per hour wind, a low coefficient of 46 being obtained.

SUMMARY AND CONCLUSION

1. Six types of revolving sprinklers for field and garden use were tested to determine the effect of wind on the water distribution pattern.
2. The tests were conducted on a field scale, the water being collected in cans placed on a 5-foot grid within the area bounded by 4 sprinklers.
3. Distribution patterns and coefficients of uniformity are presented.
4. The Rain Bird 40LA (low angle) is not recommended for field sprinkling.
5. The Rain Bird 40W produces a relatively high degree of uniformity when the sprinkler lines are placed across the path of the wind.
6. The Rain Bird 40 at a 50- by 50-foot spacing shows promise for sprinkling during periods of high winds.
7. The Rain Bird 20 is superior to the Rain Bird 20A 7° for garden irrigation on the prairies because wider spacing can be used.
8. Further study is required to obtain a greater number of comparisons and to explore wider variations of sprinkler spacings.

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